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RESEARCH MEMORANDUM

INVESTIGATION OF A THREE-BLADE PROPELLER IN COMBINATION

WITH TWO DIFFERENT SPINNERS AND AN NACA D-TYPE

COWL AT MACH NUMBERS UP TO 0.80

By George C. Kenyon and Robert M. Reynolds

Ames Aeronautical Laboratory Moffett Field, Calif.

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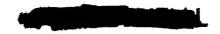
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NATIONAL ADVISORY COMMI FOR AERONAUTICS

WASHINGTON

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SUMMARY

An investigation has been made to determine the aerodynamic characteristics of a three-blade propeller designed to operate ahead of a D-type cowl. The propeller (designated NACA 3.638-(675)(057)-0572) in combination with two different spinner shapes and an NACA 1-62.8-070 D-type cowl was investigated at Mach numbers up to 0.80. The characteristics of the isolated propeller-spinner combination operating at positive thrust, negative thrust, and at near static conditions were also determined. Included are results of air-stream surveys of the local velocities in the plane of the propeller. All tests were made with the model at an angle of attack of 0° and at a Reynolds number of 1,000,000 per foot, based on free-stream conditions.

The efficiency of the propeller in the presence of the cowl was higher at all Mach numbers than that of the isolated propeller-spinner combination. At design cruise conditions (M=0.60, $\beta=53^{\circ}$), the efficiency of the propeller with the 1-series spinner and cowl was 80 percent, as compared with 72 percent for the isolated propeller-spinner combination. The onset of marked compressibility losses was delayed from a Mach number of 0.50 to a Mach number of 0.60 by the addition of the cowl.

The effects of inlet velocity ratio and spinner shape on the propeller characteristics were not large except at the higher Mach numbers (0.70 and 0.80).

INTRODUCTION

Considerable research has been conducted on propeller-spinner-cowling combinations suitable for use with large turbine engines (refs. 1 to 5). To augment this research, an investigation was conducted in the Ames



12-foot pressure wind tunnel to determine the characteristics of a three-blade propeller and a D-type cowl with both an NACA 1-series spinner and a more nearly conical spinner. The pressure-recovery characteristics of these propeller-spinner-cowling combinations have been reported in reference 6. Reference 7 has presented some preliminary results for the propeller with the cowl and spinners.

Presented herein are results of force tests, obtained concurrently with the data presented in reference 6, for the propeller operating in the presence of the cowl with the two different spinners. Also presented are force-test results for the isolated propeller-spinner combination operating at positive thrust, negative thrust, and at near static conditions. The velocity distributions in the plane of the propeller are included.

The tests were conducted for a range of blade angles from -20° to 63° and at Mach numbers up to 0.80. All tests were made with the model at an angle of attack of 0° and at a Reynolds number of 1,000,000 per foot, based on free-stream conditions.

NOTATION

speed of sound blade width power coefficient, $\frac{P}{on^{S_{0}5}}$ thrust coefficient, $\frac{T}{on^2D^4}$ Ст $e_{l_{\mathbf{d}}}$ blade-section design lift coefficient propeller diameter D HP horsepower maximum thickness of blade section h advance ratio, $\frac{V_0}{nn}$ J Mach number, $\frac{V}{8}$ M tip Mach number, $M\sqrt{1+\left(\frac{\pi}{J}\right)^2}$ M₊



- n propeller rotational speed
- P power
- R propeller-tip radius
- r blade-section radius
- S propeller disc area
- T thrust
- T_c thrust coefficient, $\frac{T}{\rho V^2 D^2}$
- U local velocity in the plane of the propeller
- V air-stream velocity
- $V_{\rm O}$ equivalent free-air velocity
- $\frac{V_1}{V_2}$ inlet velocity ratio
- β propeller blade angle at 0.75 R
- β_d design propeller-section blade angle
- η efficiency, $\frac{C_T}{C_P}$ J
- ρ air density

Subscripts

- 1 location of rake in cowl inlet
- a apparent (applied to propeller characteristics when operating ahead of the cowl)

MODEL AND APPARATUS

This investigation was conducted in the Ames 12-foot pressure wind tunnel with the model mounted on the 1000-horsepower dynamometer (described in ref. 8). A photograph of the model is presented in figure 1 and a sketch of the general model arrangement is given in figure 2. The propeller used was a three-blade type designed by Hamilton Standard Division and



it corresponded to the designation NACA 3.638-(675)(057)-0572. Blade-form curves for the propeller are shown in figure 3. Additional details of the model and its instrumentation as well as information on the full-scale design conditions can be found in reference 6.

Figure 4 is a photograph of the survey rake used to determine the velocity distribution in the plane of the propeller. The rake consisted of 24 static pressure tubes located at the radial stations listed in table I.

TESTS AND REDUCTION OF DATA

Thrust, torque, and rotational speed were measured (as described in refs. 2 and 8) for the propeller-spinner-cowl combinations and the isolated propeller-spinner combination (1-series spinner) for a range of blade angles from 33° to 63° at Mach numbers from 0.20 to 0.80. Data for the isolated propeller-spinner combination were obtained at negative thrust conditions at the same Mach numbers and blade angles and, in addition, data were obtained for this combination at a Mach number of 0.15 for blade angles from -20° to 25°. The characteristics of the isolated propeller-spinner combination were also measured at near static conditions for a blade-angle range from 10° to 25°.

Surveys of the air-stream velocity in the plane of the propeller were made at Mach numbers from 0.15 to 0.80. With the cowl installed, the effect of inlet velocity ratio on the local velocity in the propeller plane was also determined.

The Mach number used in this report was the average Mach number over the disc area as determined by velocity surveys reported in reference 8. For the tests made with the cowl installed, this Mach number (and the corresponding dynamic pressure) was corrected for blockage of the cowl by the method of reference 9. In no case did this correction exceed 1 percent.

The air-stream velocity (and, consequently, propeller advance ratio and efficiency) was corrected for the wind-tunnel-wall constraint on the propeller slipstream by the method of reference 10. Figure 5 presents a comparison of this correction with that determined experimentally by the method of reference 11 from measurements of wall pressures. The data included herein are for advance ratios at which the thrust-coefficient parameter $T_{\rm C}/(1-M^2)$ was greater than -0.5.

Analysis of the accuracy of the separate measurements of thrust, torque, and air-stream velocity, as in reference 8, indicates that errors in the propeller efficiencies reported herein are probably less than 2 percent.





RESULTS

The distribution of velocity across the propeller disc is listed in table I. These data are plotted in figure 6 for a few typical Mach numbers and inlet velocity ratios.

The characteristics of the propeller operating in the presence of the cowl are presented in figures 7 and 8 and the characteristics of the isolated propeller-spinner combination for conditions of positive thrust are presented in figure 9. The variation of maximum propeller efficiency with Mach number is summarized in figure 10 and the effect of inlet velocity ratio on the propeller characteristics is shown in figure 11.

The negative-thrust characteristics of the propeller-spinner combination are presented in figures 12 through 15 and the characteristics of the propeller-spinner combination at near static conditions are shown in figure 16 and are summarized in figure 17.

DISCUSSION

Propeller Characteristics at Positive Thrust

As in reference 2, the characteristics of the propeller operating in the presence of the cowl are presented as apparent values (figs. 7 and 8) since the determination of the propulsive thrust of the propeller was precluded by the fact that it was impractical, with the dynamometer arrangement used in the present investigation, to measure the increase in drag of the cowl and dynamometer parts within the influence of the propeller slipstream. The addition of the cowl behind the propeller resulted in reduced velocities throughout the propeller flow field, as evidenced by a comparison of figures 6(a) and 6(b) with figure 6(c). As a consequence of these reduced velocities (and in accord with the discussion of ref. 12), the thrust and power for the propeller operating ahead of the cowl were greater than that for the isolated propeller-spinner combination (at the same advance ratio), as can be seen from a comparison of figures 7 and 8 with figure 9.

Maximum efficiency.- As shown in figure 10, the efficiency of the propeller in the presence of the cowl was higher at all Mach numbers than that of the isolated propeller-spinner combination. At design cruise conditions (M = 0.60, β = 53°), the efficiency of the propeller with the 1-series spinner and cowl was 80 percent, as compared with 72 percent for the isolated propeller-spinner combination. It may be noted here that the higher efficiencies for the propeller with the cowl were due not only to interference effects but partly to the fact that, in the presence of



the cowl, the propeller was operating more nearly in the flow field for which it was designed.

The onset of marked compressibility losses was delayed (also as a consequence of the interference effects) from a Mach number of 0.50 to a Mach number of 0.60 by the addition of the cowl (fig. 10). The large losses in efficiency at Mach numbers from 0.60 to 0.80 were due not only to the effects of compressibility but also to the fact that at blade angles of 58.5° and 63° the inner portions of the blades were probably operating at negative thrust, since the local blade angles for this portion of the blade were greater than 90° (up to 98° for $\beta = 63^{\circ}$). Operation of the propeller at lower blade angles at these Mach numbers (requiring higher rotational speeds) might have resulted in higher efficiencies but was not permissible because of structural limitations of the model propeller.

Effect of inlet velocity ratio. Although the air-stream surveys (tables I(a) and I(b), and figs. 6(a) and 6(b)) show that decreasing inlet velocity ratio resulted in reduced local velocities at the propeller plane, the changes were small in comparison with the reduction in velocity occasioned by the addition of the cowl to the spinner (fig. 6(a) compared with fig. 6(c)). Consequently, as shown in figures 7, 8, and 11, the effect of inlet velocity ratio on the propeller characteristics was not large except at the higher Mach numbers (0.70 and 0.80), where small changes in local velocity resulted in relatively large changes in the propeller characteristics due to the effects of compressibility.

Effect of spinner shape. Although the data of figures 6(a) and 6(b) indicate only small differences in the local velocity distributions for the two spinners with the propeller removed, figure 11 shows that higher thrust and power coefficients were obtained with the propeller and modified conical spinner. However, as shown in figure 10, the differences in maximum efficiency were generally of the order of the stated accuracy of the results.

Propeller Characteristics at Negative Thrust

The data presented in figure 14(a) indicate that at any constant value of advance ratio, relatively constant negative-thrust coefficients were attained at blade angles from -5° to -20°. However, as shown in figure 15(a), the power coefficients corresponding to this range of blade angles increased rapidly, indicating that use of a more negative blade angle resulted in additional power absorption rather than an increase in negative thrust. For the range of blade angles and Mach numbers covered in the present investigation, there was practically no effect of compressibility on the negative-thrust and torque characteristics of the propeller at Mach numbers up to 0.60 (see figs. 14 and 15).



Propeller Characteristics at Near Static Conditions

The thrust and torque characteristics presented in figures 16(a) and 16(b) were obtained at near static conditions, as shown by the variation of velocity with nD in figure 16(c). The abrupt decrease in thrust coefficient and increase in power coefficient at values of nD below 60 are believed to be due to the effects of Reynolds number. At these low values of nD, the blade sections were operating at Reynolds numbers less than about 500,000.

The experimental data shown in figure 16 were used to compute the static thrust per horsepower and were then plotted as a function of power disc loading for constant values of nD. The envelope of these curves is presented in figure 17. The theoretical curve shown in figure 17 was computed by the method of reference 13. The variation of static thrust per horsepower with disc loading was adequately predicted by the theory, but the experimental values were only approximately 67 percent of the theoretical ideal values. However, the theory neglects rotational losses and blade drag which presumably accounts for the discrepancy between experiment and theory.

CONCLUDING REMARKS

The following remarks may be made regarding the results of the subject investigation.

The efficiency of the propeller with the two different spinners and the cowl was higher at all Mach numbers than that of the isolated propeller-spinner combination. At design cruise conditions (M = 0.60, $\beta = 53^{\circ}$), the efficiency of the propeller with the 1-series spinner and cowl was 80 percent, as compared with 72 percent for the isolated propeller-spinner combination.

The onset of marked compressibility losses was delayed from a Mach number of 0.50 to a Mach number of 0.60 by the addition of the cowl.

The effects of inlet velocity ratio and spinner shape on the propeller characteristics were not large except at the higher Mach numbers (0.70 and 0.80).

There was practically no effect of compressibility on the characteristics of the propeller-spinner combination operating at negative thrust at Mach numbers through 0.60.





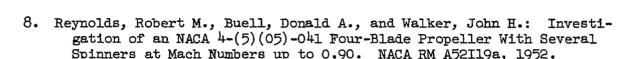
The propeller static thrust varied with power disc loading as predicted by actuator disc theory, but the experimental static thrust was only 67 percent of the theoretical ideal thrust.

Ames Aeronautical Laboratory
National Advisory Committee for Aeronautics
Moffett Field, Calif., Feb. 18, 1954

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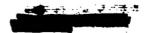


TABLE I.- LOCAL VELOCITY RATIO, U/V

(a) The 1-series spinner with cowl

Radiel		м = 0.20					N = 0,-10					N = 0.50									
atation,		Inlet velocity ratio, V1/V				Inlet valocity ratio, ₹1/▼					Inlat velocity ratio, V1/V										
in.	0.52	0.56	0.58	0.67	0.85	1,02	1.36	0735	0.40	0.52	0.61	0.80	1.00	1.33	0.29	0.39	0.50	0.60	g.8o	1,00	1.3
3.44	0.912	0.922	0.917	0.940	0.997	0.963	0.983	0.908	0.913	0.923	0.948	0.963	0.963	0.981	0.892	0.906	0.916	0.936	0.953	0.965	0.9
3.69	.916	.916	-916	.941	-951	.962	.982	.901	.912	.919	,942	-952	.962	-952	.869	-905	.913	-935	840.	-958	.9
3,94	.912	.916	.911	.936	946	.962	-977	.899	-909	-912	.939	-949	-951	-962	.883	.900	-907	.927	صاو.	.954	.9
4.19	.901	.906	.911,	.926	-936	.972	.962	.892	.902	-907	.924	-937	-947	-954	.875	-892	-896	.919	-932	.044	-9.
4.44	.905	905	.910	-925	-935	971	.961	.899	-902	-909	.927	-937	.917	952	.881	.894	-900	-919	.929	.942	-9
4.94	-900	-905	-905	.920	-930	936	956	.693	-901	-906	.918	.926	.936	عاو	.879	-686	-896	-909	.923	-927	-9
5.44	.914	.909	-91	.924	.934	-935	915	898	-908	.911	.923	-928	.936	940	.889	-898	-902	.915	-923	.929	.9
5.94	-993	-983	-918	.928	.936	-939	.944	.903	.916	.923	.931	.931	.939	942	.901	-909	-913	-921	-927	-933	9.9
6.44	.923	-983	-923	926	.939	-939	.948	,919	-918	-923	-931	.941	-939	942	903	-911	.913	921	925	.931	1.9
7. kk	.947	.947	942		917	-953	960	935	-935	-933	.940		943			926	-998	939	-939	-941	-9
8.44	-956	.956	976	.956	956	.962		95	-957	.957 .967	-979	-929	.959 .967	-962	-939	.943	-947	951	-953	.953 .961	.9
10.44	.966	.966 975	-966	.900	.976 .980	.971	971	.972	967	.970	969	.970	.970	-972 -972	953	.977 .963	957	959 963	-963 -965	-967	9
19.44	.989	984	-975 -989	.975 .984	.964	979	.979	.978	978	.978	980	.988	.978	982	.971	-973	.973	.973	976	.978	9
14.44	987	987	-987	.960	982	.982	.977	.989	984	984	987	.987	.984	.990	-975	981	-985	.983	-903	.985	و. ا
16.11	.991	991	.992	.966	-986	.986	.981	.986	981	981	.983	.984	980	989	981	981	.903	981	.981	981	6.
16.44	.990	.990	.990	.985	.985	.990	.990	.988	988	.988	968	988	.986	996	.980	.986	966	.984	984	.986	ۇ. ا
20.14	.990	.990	.990	.990	.990	995	-995		992		995	-993	993	993	.986	989	-990	.080	990	.992	.9
22.14	.989	.909	.909	-984	-984	989	989	993	.989	993 980	991	.989	992	.002	-991	987	.987	.989 .987	-987	.987	و. ا
24.44	999	999	.000	.ook	-994	.999	.999	990	.993	993	.996	998	.996	.992 .996	994	.992	.992	- 990	990	.992	1 .9
26.44	-993	-993	.999 .988	.993	988	-993	.999 .986	-997	995	995	997	995	995	.995	990	.990	990	991	.994	-994	1 .9
28.14	993	-993	-993	.993	-993	.998	-993	.996	996	-996	.996	-996	.994	.996	-993	.995	.994	993	-993	-995	1 .9
30.44	-993	993	996	-998	-993	.998	-998	995	-993	-995	995	995	-993	-993	.987	-991	-591	.991	-989	.991	1 .9
32.44	-997	-997	-997	-997	-997	-999	-997	-999	-999	-999	.996	-997	-997	-999	.994	-999	.998	.996	.998	-996	1.9
	Redial				W = 0.6			N = 0.70					N = 0.60				\vdash				
	station,	ж - 0.60										As						1			
- 1	in.	Inlet velocity ratio, V₁/V						_			y retio			Inlet velocity ratio, V1/V				4			
L		0.32	0.41	0.52	0.62	0.84	1.03	1.26	0.32	0.41	0.51	0.67	0.82	1.07	0.32	0.41	0.51	0.62	0.82	0.96	4
- 1	3.44	0.898	0.914	0.936	0-937	0.953	0.964	0.971	0.897	0.915	0.926	0.936	0.946	0.957	0.881	0.905	0.916	0.927	0.949	0.946	Į.
	3.69	.898	.908	926	933	.950	-979	.966	892	.912	925	-933	946	-977	.877	905	.915	.936	-936	,ghi	Į.
1	3.94	.891		.926	998	.943	-950	.954	-885	.906	-916	924	-935	.945	.872	896	.905	.915	928	.932	1
	4.19		.905																		1
		.863	.895	.914	.916	.931	.936	.947	-874	.894	.905	-911	.923	•933	.860	-886	.895	905	.914	.920	1
- 1	h. 44	.885 .886	.895	.914 .917	.926	.931 .989	.940		.879	.894 .895	.905 -905	.911	.923 -923	·933	.860 .860	.885	.895	905	.914	.920	1
l	14. 14. 14. 19.14	.886 .886	.895 .897 .893	.914 .917 .910	.911	.931 .989 .986	.940 .931	.947 .945 .932	.879 .874	.894 .895 .886	.905 .905 .895	.911 .905	.923 .923	·933 ·931 ·982	.860 .860 .877	.886 .885	.895 .894 .886	.905 .904 .896	.914 .911	.920 .922	
	4.94 5.44	.883 .886 .883 .891	.895 .897 .893 .898	.914 .917 .910 .910	.911 .911	.931 .989 .926 .92k	.940 .931 .928	.947 .945 .933	.879 .874 .882	.894 .895 .886 .891	.905 .905 .895 .899	911 905 904	.923 .923 .914 .913	.933 .931 .982	.860 .860 .857 .863	.886 .885 .877	.895 .894 .886	.905 .904 .896 .893	.914 .911 .904	.922 .922 .910	
	4.94 5.44	.885 .886 .883 .891 .903	.895 .897 .893 .898 .907	.914 .917 .910 .910	.916 .911 .916	.931 .989 .926 .924	.940 .931 .928 .931	.947 .945 .933 .933	.879 .874 .882 .891	.894 .895 .886 .891 .897	.905 .905 .895 .899	.911 .905 .904 .908	.923 .914 .913 .916	.933 .931 .982 .919	.860 .860 .857 .863 .868	.886 .885 .877 .878	.895 .894 .886 .886	.905 .904 .896 .893 .897	.914 .911 .904 .904	.920 .922 .910	
	1.44 1.94 5.44 5.94 6.44	.883 .886 .883 .891 .903	.895 .897 .893 .898 .907	.914 .917 .910 .910 .919 .921	.916 .911 .916 .916	.931 .989 .926 .924 .929	.940 .931 .928 .931	.947 .945 .933 .933 .935	.879 .874 .882 .891 .892	.894 .895 .886 .891 .897 .898	.905 .905 .895 .899 .905	.905 .904 .908 .907	.923 .923 .914 .913 .916	933 931 982 939	.860 .860 .877 .863 .868 .873	.886 .885 .877 .878 .895	.895 .894 .886 .886 .891	.905 .904 .896 .893 .897	.914 .911 .904 .906 .906	.920 .922 .910 .910	
	1.44 1.94 5.44 5.94 6.44 7.44	.885 .886 .883 .891 .903 .905 .926	.895 .897 .893 .898 .907 .912	.914 .917 .910 .920 .921 .921	.916 .911 .916 .916	.931 .989 .926 .924 .929 .989	.940 .931 .928 .931 .931	.947 .935 .935 .935 .936 .938	.879 .874 .882 .891 .892 .912	.894 .895 .886 .891 .897 .896	.905 .895 .899 .899 .905 .905	.905 .905 .908 .908 .907	.923 .923 .914 .913 .916 .914	.933 .931 .982 .919 .919	.860 .857 .863 .868 .873 .896	.886 .885 .877 .878 .895 .886	.895 .894 .886 .886 .891 .891	.905 .904 .896 .893 .897	.914 .911 .904 .905 .906 .902	.920 .922 .910 .910 .910	
	4.94 5.44 5.94 6.44 7.44	.883 .886 .883 .991 .903 .905 .926	.895 .897 .893 .898 .907 .918 .926	.914 .917 .910 .910 .921 .940 .950	.916 .916 .916 .916 .930	931 989 926 924 989 938 938	.940 .931 .928 .931 .931 .936	.947 .937 .937 .935 .935 .938 .938	.879 .874 .882 .891 .892 .912 .933	.894 .895 .886 .891 .898 .916	.905 .905 .895 .899 .905 .905 .919	.911 .905 .908 .908 .907 .922	.923 .914 .913 .916 .914 .925	931 931 931 932 933 933 933 933 933 933 933 933 933	.860 .863 .863 .873 .873 .896	.886 .885 .877 .878 .885 .900	.895 .894 .886 .886 .891 .891 .923	.903 .904 .896 .893 .897 .907	.914 .911 .904 .906 .908 .908	.920 .921 .910 .910 .916	
	1.44 5.44 5.44 7.44 8.44 9.44	.883 .886 .883 .991 .903 .905 .926 .945	.895 .897 .893 .898 .907 .912 .926 .947	.914 .917 .910 .919 .921 .940 .950	.916 .916 .916 .916 .930	931 989 986 984 989 939 930	.940 .931 .928 .931 .935 .936	.947 .953 .953 .953 .953 .953 .953 .953 .953	.879 .872 .882 .891 .892 .912 .933	.894 .895 .886 .891 .896 .916 .936	.907 .897 .899 .907 .905 .919 .937	905 908 908 908 908 908 909	.923 .914 .913 .916 .914 .925	955 955 955 955 955 955 955 955 955 955	.860 .857 .863 .868 .673 .896 .927	.886 .887 .877 .878 .886 .900 .921 .939	855 886 886 887 887 887 887 887 887 887 887	953 954 955 957 957 957 959 959	.914 .904 .904 .906 .908 .912 .928 .944	.920 .921 .910 .910 .916 .935 .948	
	1.44 5.44 5.44 7.44 7.44 9.44	.863 .886 .883 .891 .903 .905 .926 .945 .961	.895 .897 .893 .898 .907 .912 .926 .947 .961	.914 .917 .910 .919 .921 .940 .950 .965	.916 .916 .916 .916 .916 .919 .919	931 986 986 989 989 989 989 989 989 989	.940 .931 .928 .931 .936 .936 .956	.947 .933 .933 .933 .933 .933 .933 .934	.879 .882 .891 .892 .912 .933 .951	.894 .895 .896 .897 .896 .916 .936 .932	.905 .895 .899 .905 .905 .919 .937 .950	901 908 907 928 939 934	.923 .914 .913 .914 .925 .940	95 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	868 568 556 555 556 555 556 555 556 555 556 55	.886 .885 .877 .876 .885 .886 .900 .921 .939	.855 .836 .836 .831 .833 .939 .938	.907 .904 .896 .893 .897 .928 .928 .939	.914 .904 .906 .906 .908 .912 .928 .944	.920 .921 .930 .930 .935 .935 .948	
	1.45 1.94 5.44 7.46 8.44 9.46 10.44	.863 .886 .883 .891 .903 .905 .926 .945 .962	.895 .897 .893 .898 .907 .918 .926 .947 .961	.914 .917 .910 .919 .921 .940 .950 .965	.916 .916 .916 .916 .916 .919 .901 .901	.931 .989 .986 .989 .989 .989 .989 .989 .989	.940 .931 .928 .931 .936 .936 .956	.947 .933 .933 .933 .933 .933 .933 .934	.879 .874 .882 .891 .892 .912 .933 .951 .952	.894 .895 .886 .891 .897 .896 .916 .936 .932	.905 .905 .895 .899 .905 .905 .919 .937 .950	900	.923 .914 .913 .916 .914 .925 .940 .950	933 934 939 939 939 939 939 939 939 939	.860 .863 .863 .863 .873 .896 .937 .936	.886 .885 .877 .876 .885 .900 .921 .939 .939	85.486 886 886 886 886 886 886 886 886 886	.907 .904 .896 .893 .897 .928 .949 .949	.914 .904 .906 .906 .908 .912 .928 .944 .942	.920 .922 .910 .910 .916 .916 .918 .948 .948	
	5.44 5.44 5.44 7.44 9.44 10.44 14.44	.863 .886 .883 .991 .903 .905 .926 .945 .961 .962	.895 .897 .898 .907 .912 .926 .947 .961 .961 .973	.914 .917 .910 .919 .921 .940 .950 .965	.926 .911 .916 .916 .930 .949 .964 .968 .968	931 989 986 988 989 989 989 988 989 988 988	.940 .931 .928 .931 .935 .936 .964 .964	947 935 935 935 935 938 938 938 938 938 938 938	.879 .874 .882 .891 .912 .933 .951 .976	.894 .895 .886 .891 .896 .916 .936 .932 .932 .964	.905 .905 .895 .899 .905 .905 .919 .937 .950 .952 .964	911 905 908 908 907 928 939 954 954	.923 .914 .913 .916 .914 .925 .940 .973 .970	35.55.55.55.55.55.55.55.55.55.55.55.55.5	860 860 863 863 873 865 873 873 873 873 873 873 873 873 873 873	.886 .887 .877 .878 .886 .900 .921 .939 .939 .939	895 894 886 886 881 881 983 989 989	.907 .904 .896 .897 .907 .907 .908 .909 .909 .909	.914 .904 .904 .906 .908 .912 .944 .948 .949 .949	.920 .922 .910 .910 .916 .916 .948 .948 .948	1
	5.44 5.44 5.44 7.44 9.44 10.44 16.44	.863 .886 .883 .891 .903 .925 .945 .945 .962 .962 .989	.895 .897 .893 .898 .907 .912 .926 .947 .961 .973 .981	.914 .917 .910 .910 .919 .921 .940 .956 .967 .967 .969	.926 .911 .916 .916 .930 .949 .964 .968 .968 .969	931 989 986 986 989 989 989 989 989 988 987 988	.940 .931 .928 .931 .935 .936 .936 .936 .936 .936 .936 .936 .936	947 935 935 935 935 938 938 938 938 938 938 938	.879 .874 .882 .891 .912 .933 .911 .926 .964 .976	.894 .895 .886 .897 .898 .916 .936 .932 .932 .976 .978	.905 .905 .899 .905 .905 .919 .937 .950 .954 .973	911 905 908 908 907 928 939 939 954 951 951	\$33 \$34 \$35 \$35 \$35 \$35 \$35 \$35 \$35 \$35 \$35 \$35	33.55.55.55.55.55.55.55.55.55.55.55.55.5	36 95 96 95 95 95 95 95 95 95 95 95 95 95 95 95	.886 .885 .876 .886 .900 .921 .939 .939 .967	85.846.856.855.959.955.955.955.955.955.955.955.955	\$5.50 \$5.50	.914 .904 .904 .906 .908 .912 .942 .942 .949 .977 .966	.920 .922 .910 .910 .916 .915 .918 .918 .918 .918 .918	
	5.44 5.44 5.44 7.44 9.44 10.44 14.44 16.44	.883 .886 .883 .891 .905 .905 .945 .962 .962 .963 .963	.895 .897 .893 .898 .907 .912 .926 .947 .961 .961 .961	.914 .917 .910 .910 .921 .940 .950 .967 .967 .968 .989	.926 .911 .916 .916 .930 .949 .959 .968 .960 .979	93.98.64.89.99.99.99.99.99.99.99.99.99.99.99.99.	.940 .931 .928 .931 .935 .936 .966 .977 .982 .988	4488888884458888	.879 .874 .892 .891 .993 .991 .998 .964 .976 .964	.895 .886 .897 .896 .996 .998 .998 .978 .978 .978 .978	.905 .905 .895 .905 .905 .919 .937 .954 .964 .963	911 905 908 907 929 939 939 954 978 978	\$3.54 \$3.54 \$3.54 \$3.55	HHHHHHHHHHHH	\$6.50 \$6.50	.886 .885 .876 .886 .900 .921 .939 .939 .953 .953 .953 .953	85.848.851.851.939.955.556	\$54 \$65 \$55 \$55 \$55 \$55 \$55 \$55 \$55 \$55 \$55	.914 .904 .906 .906 .908 .912 .944 .942 .942 .955 .950	.922 .921 .921 .932 .933 .934 .935 .935 .935 .935 .935 .935 .935 .935	
	5.44 5.44 5.44 7.44 10.44 12.44 16.44 16.44	.883 .886 .883 .903 .905 .945 .964 .962 .963 .968 .968	.895 .897 .893 .898 .901 .947 .961 .961 .961 .963 .988 .998	.914 .917 .910 .919 .921 .950 .967 .967 .965 .969 .999	.946 .911 .916 .916 .916 .916 .917 .918 .919 .919 .919 .919 .919 .919 .919	931 986 988 988 988 988 988 988 988 988 988	.940 .931 .928 .931 .935 .936 .966 .977 .982 .988	4488888884458888	.879 .874 .892 .891 .993 .993 .995 .964 .979 .968	.895 .886 .851 .896 .936 .936 .978 .978 .978 .978 .984	.905 .905 .895 .905 .905 .937 .959 .954 .971 .983 .986	91.50 \$ 50 \$ 50 \$ 50 \$ 50 \$ 50 \$ 50 \$ 50 \$	\$63 \$64 \$13 \$15 \$15 \$15 \$15 \$15 \$15 \$15 \$15 \$15 \$15	\$3.500 \$3	860 860 860 860 860 860 860 860 860 860	.886 .885 .877 .878 .886 .900 .921 .939 .939 .939 .973 .972 .972	895,886 886,885 886,885 887,989 939 939 956,966 963	\$54 \$65 \$55 \$55 \$55 \$55 \$55 \$55 \$55 \$55 \$55	.914 .911 .904 .906 .908 .912 .944 .942 .975 .966 .970 .970	.922 .921 .920 .930 .930 .935 .935 .948 .955 .955 .955 .955	
	5.44 5.44 5.44 7.44 9.44 10.44 14.44 16.44 16.44 20.44	.883 .886 .883 .903 .903 .905 .962 .962 .962 .963 .969	.895 .897 .893 .898 .907 .940 .940 .940 .940 .940 .940 .940 .940	.914 .917 .910 .920 .921 .940 .950 .967 .965 .969 .995	.916 .911 .916 .916 .916 .919 .929 .939 .939 .939 .939 .939 .939 .93	93.88.64.88.88.88.88.88.88.88.88.88.88.88.88.88	.940 .931 .928 .931 .936 .936 .964 .966 .977 .982 .983 .988 .988	**************************************	879 882 891 892 993 991 995 964 976 976 978 988	.895 .895 .896 .897 .896 .998 .998 .976 .976 .978	.905 .905 .895 .905 .905 .907 .904 .904 .903 .904 .903 .905 .905	51.55 \$6.55 \$8.55 \$5.55 \$6.55	\$63.4 \$13.5 \$15.5	**************************************	\$60 50 50 50 50 50 50 50 50 50 50 50 50 50	.886 .887 .876 .886 .980 .939 .939 .939 .939 .971 .972 .984	895,886 886,885 886,885 887,889 988,986 986,986	\$54 \$55 \$55 \$55 \$55 \$55 \$55 \$55 \$55 \$55	.914 .904 .906 .908 .908 .912 .944 .942 .975 .966 .970 .970 .970 .970	.922 .921 .920 .930 .930 .935 .935 .948 .955 .978 .978 .978	
	1.45 1.94 5.44 5.44 7.44 9.44 10.44 11.44 16.44 16.44 20.44 24.44	.863 .866 .863 .903 .905 .926 .945 .963 .963 .963 .963 .963 .963 .963 .963	.895 .897 .893 .896 .926 .926 .941 .940 .941 .980 .984 .984 .988 .988	.914 .917 .910 .920 .921 .940 .950 .967 .965 .965 .965 .990 .995	.946 .911 .916 .916 .916 .919 .929 .929 .939 .939 .939 .939	931 938 938 938 938 938 938 938 938 938 938	.940 .931 .938 .931 .938 .939 .964 .966 .977 .962 .963 .963 .989 .989	\$75000000000000000000000000000000000000	879 882 892 913 933 931 954 964 967 988 987 989	.855 .855 .856 .857 .958 .936 .958 .958 .958 .958 .958 .958 .958 .958	.905 .905 .899 .905 .905 .905 .907 .909 .909 .909 .909 .909 .909 .909	見から の の の の の の の の の の の の の	\$4.50.54 \$5.54 \$5.55 \$5.	\$3.50 \$3.50	\$60 550 550 550 550 550 550 550 550 550 5	886 887 886 980 939 937 957 957 958 966	85.866 886.851 887.959 987.955 986.955 986.955	\$54 \$55 \$55 \$55 \$55 \$55 \$55 \$55 \$55 \$55	.914 .904 .904 .908 .912 .928 .944 .942 .971 .962 .965	.922 .922 .920 .920 .930 .930 .948 .948 .948 .957 .972 .978 .978 .978	
	1.40 1.54 5.44 5.44 7.44 10.44 11.44 11.44 20.44 20.44 20.44	.883 .886 .883 .905 .905 .905 .905 .905 .905 .905 .905	.899 .897 .893 .898 .907 .903 .904 .903 .904 .904 .905 .905 .905 .905 .905 .905 .905 .905	.914 .917 .910 .920 .921 .940 .956 .967 .963 .985 .995 .995	.926 .931 .936 .936 .939 .949 .968 .979 .961 .989 .989 .989	93.884.888.888.888.888.888.888.8888.8888	.940 .931 .928 .938 .938 .938 .936 .936 .936 .938 .938 .939 .938 .939 .939 .939 .939	\$7.5000000000000000000000000000000000000	879 882 892 913 914 915 954 956 968 969 969 969	895 885 885 885 886 986 986 978 978 978 984 987 987	.905 .905 .899 .905 .905 .909 .934 .964 .963 .989 .989 .989	51.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	\$4 \$34 \$34 \$35 \$35 \$35 \$35 \$35 \$35 \$35 \$35 \$35 \$35	£	\$.886 .887 .878 .886 .900 .921 .939 .939 .957 .964 .966 .966	854 886 881 881 881 881 881 881 881 881 881	\$0.54 \$63 \$63 \$55 \$55 \$55 \$55 \$55 \$55 \$55 \$55 \$55 \$5	.914 .904 .904 .908 .912 .928 .944 .942 .970 .965 .965 .984	.922 .922 .923 .934 .935 .935 .935 .935 .935 .935 .935 .935	
	1.60 1.04 5.44 7.44 8.44 10.44 11.44 11.44 11.44 20.44 24.44 26.44	883 886 883 893 905 905 905 905 905 905 905 905 905 905	.895 .897 .898 .907 .918 .926 .940 .951 .961 .973 .980 .984 .989 .989 .989	.914 .917 .919 .920 .921 .940 .967 .967 .969 .995 .995 .995 .995	.914 .914 .916 .916 .929 .939 .939 .939 .939 .939 .939 .939	93.88.48.88.88.88.88.88.88.88.88.88.88.88.	.940 .931 .928 .931 .938 .938 .936 .966 .970 .988 .989 .999 .999 .999	\$75000000000000000000000000000000000000	879 882 882 882 893 953 954 956 959 953 954	854 855 855 856 856 958 958 958 958 958 958 958 958 958 958	.905 .905 .905 .905 .905 .905 .905 .905	91994 9194 916 916 916 916 916 916 916 916 916	\$434 \$435 \$45 \$45 \$45 \$45 \$45 \$45 \$45 \$45 \$45 \$4		\$65.538 \$75.54 \$75.55 \$45.55 \$65.55 \$75.55 \$.886 .887 .876 .885 .886 .900 .939 .939 .973 .975 .984 .986 .986	8554 886 886 881 883 983 985 985 985 985 985 985 985 985 985 985	\$54.855555555555555555555555555555555555	914 906 906 908 912 912 944 977 986 971 982 987 987 989 989	.922 .922 .923 .934 .935 .935 .935 .935 .935 .935 .935 .935	
	1.40 1.54 5.44 5.44 7.44 10.44 11.44 11.44 20.44 20.44 20.44	.883 .886 .883 .905 .905 .905 .905 .905 .905 .905 .905	.899 .897 .893 .898 .907 .903 .904 .903 .904 .904 .905 .905 .905 .905 .905 .905 .905 .905	.914 .917 .910 .920 .921 .940 .956 .967 .963 .985 .995 .995	.926 .931 .936 .936 .939 .949 .968 .979 .961 .989 .989 .989	93.884.888.888.888.888.888.888.8888.8888	.940 .931 .928 .938 .938 .938 .936 .936 .936 .938 .938 .939 .938 .939 .939 .939 .939	\$7.5000000000000000000000000000000000000	879 882 892 913 914 915 954 956 968 969 969 969	895 885 885 885 886 986 986 978 978 978 984 987 987	.905 .905 .899 .905 .905 .909 .934 .964 .963 .989 .989 .989	51.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	\$4 \$34 \$34 \$35 \$35 \$35 \$35 \$35 \$35 \$35 \$35 \$35 \$35	£	\$.886 .887 .878 .886 .900 .921 .939 .939 .957 .964 .966 .966	854 886 881 881 881 881 881 881 881 881 881	\$0.54 \$63 \$63 \$55 \$55 \$55 \$55 \$55 \$55 \$55 \$55 \$55 \$5	.914 .904 .904 .908 .912 .928 .944 .942 .970 .965 .965 .984	.922 .922 .923 .934 .935 .935 .935 .935 .935 .935 .935 .935	

TABLE I.- LOCAL VELOCITY RATIO, U/V - Continued

(b) Modified conical spinner with cowl

Redial	X = 0.20					N = 0.No					M = 0.50							
station,		Inlet valonity ratio, V1/V				Inlet velocity ratio, V1/V					Inlet velocity ratio, V1/V							
in.	0.18	0.55	0,65	48.0	1.02	1.36	0.43	0.53	0.63	98.0	0.96	1.35	0.42	0.53	0.63	0.83	1.04	1.3
3.34	0.881	0.897	0.912	0.927	0.937	0.954	0.871	6.900	0.905	0.920	0.928	0.945	0.866	0.897	0.903	0.920	0.926	0.9
3.29	.885	-901	.911	.926	.941	956	870	.899	924	.919	.929	, juli	.863	-898	.904	.917	-929	.9
3. 2 9 3.84	.885	.901	-911	.926	.936	956	.870	.896	.922	.917	926	.910	.861	-898 -888	.900	.915	-925	.9
4.09	.880	.896	.906	.916	.931	.916	868	.894	899	.909	.919	.932	859	-888	694	.907	.917	1 .9
4.34	884	.900	-910	.915	.930	945	-875	.896	-904	.914	.919	.932	.863	890	.898	.911	-915	.9
4.84	.884-	.895	910	915	.925	-940	.877	.893	-900	.908	.915	925	.868	-868	.896	.907	.913	.9
5.34 5.84	.898	-909	.919	929	.934	939	.890	.903	.905	•916	.920	.928	.869	-896	.902	.911	.917	.9
5.84	.908	.913	-923	-933	.938	943	.905	.910	.912	.921	.925	.933	.894	.907	.923	.913	-993	
6.34	.918	.913	923	-933	938 917	.949	906	.916	.938	.922	928	936	.898	-909	.913	.915	-923	.9
7.34	.012	-937	.947	.917	917	957	.998	-930	-930	-935	937	.940	-920	-926	996	.934	.936	.5
8.34	946	932	956	.956	.961	.961	.949	-949	واو	956	977	-977	940	.945	947	950	-949	9.9
9.34	966	.954	-971	.971	.977.	.976	.964	.962	962	96)	.964	.967	957	-959	961	-959	.961	-9
10.34	975	.975	-980	.900	900	-985	.967	967	.981	.968	967	.967	.963	965	.965	963	-965	و. ا
12.34	984	984	-989	.989	.989	-989	-9(5	973	-973	973	-975	-975	915	-973	973	-982	-973	.9
14.34	.987	.982	987	.987	987	987	.987	.984	-984	.984	.984	984	-985	.985	.985	.918	984	5
16.34	.991	-986	.991	.991	.991	.991	.903	.981	901	981	981	.981	-983	,983	963	985	-963	۱ ۰۶
18.34	.990	•990	995	995	995	-990	.983	.983	983	-983	966	.983	.986	.986	.966	986	-986	۱ .5
20.34	-995	-995	1,000	.995	995	1.000	.998	.982	-992	-989	-992	.999	.994	.990	.990	.986	-992	.5
22.3h	.989	-969	-991	.994	.994	.994	.994	.961	.991	.988	-991	.990	.969	.991	.991	-997	969	۱ ۰۶
24.34	.999	999	1.004	1.004	1.004	1.004	.998	.990	.996	•996	993	-993	-996	.996	.996	.998	.994	(.5
26.34	-993	988	•993	-993	.998	-998	-997	.969	-995	-995	995	-995	.996	.996	.996	-996	-994	-5
28.34	.993	1.003	1.003	1.003	1.003	1.003	.996	988	994	-99	1994	.994	995	-995	995	-997	-995	1 .5
30.34	.998	1.000	1.003	1.003	1.008	1.003	-993	-993	-990	.990	993	993	991	.991	993	-991	-993	و. ا
32.34	997	1.002	1.007	1.007	1.002	1.007	-997	989	.994	1994	997	-997	.998	1.000	1.000	1.000	1.000	1 .5
Redial	-		K =	0.60					N - 1	0.70			-		м -	0.80		
stabion.		Talet	valonit	y ratio	. V. /v			Inlet	velocit;		. 4./7		Inlet valocity ratio, V1/V					
in.	0.34	0.43	0.54	0.65	0.85	1.05	0.32	0.42	0.50	0.62	0.82	1.11	0.30	0.41	0.52	0.62	0.82	0.9
2 24	0.867	0.885	0.893	0.898	0.912	0.917	0.856	0.880	0.883	0.891	0.907	0.916	9.838	0.865	0.874	0.884	0.894	0.9
3.34		.888					.856	.882	885	.895	.907	.919	.841	.867	.875	.884	.897	
3.59 3.84	.872		.901, .898	.902	91.6	920	963	877	.880	888	.901	.911	.837	.861	.870	880	.890	.8
			.090		907	.917	.853 .847	B70	.073	882	.893	.904	.830	855	863	872	.682	1.8
	.867	.683	one														100	
4.09	.867	.878	.886	.891			Beta			A Dec						Bri	883	
4.09	.867 .867	.878	.888	.895	.902	912	.851	.073	.880	.885	.896	.907	.836	-857	.866	874	.883	3,
4.09 4.34 4.84	.867 .867 .868	.878 .879 .879	.888	.893	.902 .900	-912 -907	.851 .853	.873	.880 .876	.885	.896 .890	.907	.836 .834	.857 .855	.866 .860	879	.882	
4.09 4.34 4.84 5.34	.867 .867 .868 .880	.878 .879 .879	.888 .886 .893	.893 .896	.902 .900	.912 .907 .909	.851 .853 .863	.873 .870 .880	.880 .876 .883	.885 .883 .888	896 890 896	.907 .899	.836 .834 .844	.857 .855 .862	.865 .862 .867	.874 .872 .875	.882 .883	. i
1.09 1.34 1.84 5.34 5.84	.867 .867 .868 .880 .893	.878 .879 .879 .886	.888 .886 .893	.893 .896 .905	.902 .900 .908	.912 .907 .909	.851 .853 .863 .878	.873 .870 .880 .889	.880 .876 .883 .891	.885 .883 .888	.896 .890 .896 .904	.907 .899 .904	.836 .834 .844	.857 .855 .862 .870	.866 .862 .867	.872 .872 .875	.882 .883 .890	
4.09 4.34 4.84 5.34 5.84 6.34	.867 .867 .868 .880 .893 .898	879 879 886 887 886	.888 .886 .893 .900	.895 .893 .896 .905	.902 .900 .902 .910	.912 .907 .909 .917	.853 .863 .863 .878	.873 .870 .880 .889	.880 .876 .883 .891 .891	.885 .883 .886 .895	.896 .896 .904 .904	.907 .899 .904 .910	.836 .834 .844 .807 .862	.857 .855 .862 .870	.865 .862 .867 .875	.874 .872 .875 .883	.862 .883 .890 .891	
4.09 4.34 4.84 5.84 5.84 7.34	.867 .868 .880 .893 .898	878 879 886 887 886 887	.888 .886 .893 .900 .903	.893 .896 .905 .909	.902 .900 .902 .910 .914 .928	.912 .907 .909 .917 .917	853 8678 868 868 868	.873 .870 .880 .889 .892 .909	.883 .891 .891 .991	.885 .888 .895 .897	.896 .896 .904 .904	.907 .899 .904 .910 .910	.836 .834 .844 .857 .862 .886	.857 .855 .862 .870 .874	.866 .862 .867 .875 .879	.879 .879 .875 .889 .884	.882 .883 .890 .891 .903	
4.09 4.34 4.84 5.84 5.34 7.34	.867 .869 .890 .893 .896 .919	879 879 886 886 887 887 887 887 887 887 887 887	.888 .886 .893 .901 .903 .921 .948	.893 .896 .905 .909 .921	902 900 902 910 914 988 943	.912 .907 .909 .917 .926 .943	.853 .863 .878 .883 .986	.873 .870 .880 .889 .892 .909	.880 .876 .883 .091 .912 .912	.885 .888 .895 .897 .913	.896 .896 .904 .904 .919	.907 .899 .904 .910 .910	.836 .834 .844 .897 .862 .886	.857 .855 .862 .870 .874 .891	.865 .862 .867 .875 .879 .896	.874 .872 .875 .883 .884 .900	.862 .883 .890 .891 .903	
4.09 4.34 4.34 5.84 7.34 7.34 9.34	.867 .869 .880 .893 .939 .939	879 879 879 886 887 887 897 897 897 897 897 897 897 897	.888 .886 .893 .901 .903 .921 .948	.893 .896 .999 .921 .941	902 900 908 910 914 988 943	.912 .907 .909 .917 .928 .943	.853 .853 .863 .864 .986 .986	.873 .870 .880 .899 .999 .933 .946	.860 .883 .884 .883 .884 .883 .883 .883 .883	.885 .888 .895 .897 .933 .948	896 896 904 904 919 935	.907 .999 .904 .910 .910 .922 .938	.836 .834 .844 .862 .886 .910	.857 .859 .862 .870 .874 .894 .916	.865 .862 .867 .875 .879 .896 .918	.874 .872 .875 .883 .884 .900 .993	.882 .883 .890 .891 .903 .924	.8
4.09 4.84 5.84 5.84 5.84 7.84 7.84 7.84 7.84 7.84 7.84 7.84 7	.867 .869 .860 .893 .896 .939 .939	879 879 886 886 897 936 936 937	.888 .886 .893 .901 .903 .921 .948 .975	.893 .896 .909 .921 .941 .975	902 900 908 919 914 988 943	.912 .907 .909 .917 .926 .943 .959	650 650 650 650 650 650 650 650 650 650	.873 .870 .880 .889 .992 .909 .933 .946	.880 .876 .883 .994 .919 .919 .916	.885 .886 .895 .897 .933 .948 .949	896 896 904 904 919 935 944	.907 .999 .904 .910 .910 .982 .938 .946	.836 .834 .844 .857 .869 .910 .911	.857 .852 .870 .874 .894 .916 .934	.866 .862 .867 .875 .879 .896 .918 .935	.874 .872 .875 .883 .884 .900 .993 .937	.862 .883 .890 .891 .903 .924 .940	.8 .8 .8 .9 .9
4.09 4.84 5.84 5.84 7.84 7.84 7.84 7.84 7.84 7.84 7.84 7	.867 .869 .860 .898 .898 .975 .975 .975 .975 .975	865 885 935 935 935 935 935 935 935 935 935 93	.888 .886 .893 .901 .903 .921 .948 .979 .979	.893 .896 .909 .921 .911 .975 .972	.902 .900 .910 .914 .928 .943 .959	917 927 927 927 927 928 943 959 959	\$5.50 \$5.50	.873 .870 .880 .889 .999 .933 .946 .940	880 883 984 985 983 984 985 985 985 986	.885 .886 .895 .897 .933 .948 .948 .964	896 896 904 904 919 919 919 944 969	907 904 910 910 982 938 946 938	.836 .834 .807 .862 .886 .910 .931	.857 .852 .870 .874 .894 .916 .934	.865 .862 .867 .875 .879 .896 .918 .935 .918	.874 .879 .889 .884 .900 .993 .910 .925	.882 .883 .890 .891 .903 .924 .940 .922	.8 .8 .8 .9 .9
4.09 4.34 4.84 5.84 5.84 5.84 7.84 9.34 12.34	.867 .869 .880 .893 .896 .939 .957 .960 .954	.878 .879 .886 .897 .996 .997 .995 .997	.888 .886 .893 .901 .903 .921 .948 .979 .970	.893 .896 .995 .909 .921 .914 .975 .979 .979	.902 .902 .914 .924 .925 .937 .959 .979	.912 .907 .909 .917 .928 .943 .955 .959 .970	55. 553. 553. 553. 554. 554. 554. 554. 5	.873 .870 .880 .889 .992 .993 .946 .940 .964	.850 .876 .883 .991 .933 .935 .935 .936 .936 .936	885 885 895 897 933 948 956 976	.896 .896 .904 .904 .919 .935 .944 .969	.907 .899 .904 .910 .910 .922 .938 .946 .938 .965	.836 .834 .857 .869 .886 .910 .915 .951	.857 .859 .870 .874 .894 .916 .934 .938 .938	.865 .867 .875 .879 .896 .918 .935 .918	.874 .872 .875 .883 .900 .903 .917 .910	.882 .883 .890 .891 .903 .924 .940 .922 .942	.8
4.09 4.34 4.84 5.84 5.84 5.84 7.83 14.34 14.34	.867 .868 .880 .893 .898 .939 .937 .957 .962 .981	.878 .879 .879 .886 .897 .936 .937 .936 .954	.688 .886 .893 .901 .903 .921 .948 .975 .979 .960 .977	.893 .896 .995 .909 .921 .914 .975 .979 .979	.902 .900 .908 .910 .914 .988 .955 .979 .979	.912 .907 .909 .917 .928 .943 .955 .959 .979	55. 553. 553. 553. 554. 554. 554. 554. 5	.873 .870 .880 .889 .992 .993 .946 .940 .964	880 883 894 995 995 995 995 995 995 995 995 995 9	.885 .888 .895 .897 .913 .918 .948 .964 .976	.896 .896 .994 .919 .935 .935 .944 .969 .976	.907 .899 .904 .910 .910 .922 .938 .946 .938 .965	.836 .834 .844 .807 .869 .886 .910 .915 .915 .951	.857 .859 .870 .874 .916 .934 .938 .938 .954	.866 .862 .867 .875 .879 .896 .918 .935 .918 .955	.874 .872 .875 .883 .900 .903 .910 .910 .957 .913	.882 .883 .890 .891 .903 .924 .940 .922 .942 .942	.8.6.6.6.6.6.6.6.6.6.6.6.6.6.6.6.6.6.6.
4.09 4.84 5.83 5.83 5.83 9.02 124 135 135 146 135 146 135 146 146 146 146 146 146 146 146 146 146	\$6.50 \$6.50	\$5.585555555555555555555555555555555555	.888 .893 .904 .903 .948 .979 .960 .977 .963	.893 .896 .905 .909 .921 .941 .975 .979 .978 .978	.902 .902 .914 .928 .943 .955 .979 .979	.912 .907 .909 .917 .928 .943 .959 .979 .979	\$5555555555555555555555555555555555555	.873 .870 .880 .889 .999 .933 .940 .956 .956 .956	880 876 883 984 984 985 986 986 986 986 986 986 986 986	.883 .888 .895 .897 .913 .948 .948 .976 .978	.896 .896 .904 .904 .919 .935 .976 .976 .976	.907 .899 .910 .910 .910 .910 .910 .910 .910 .9	.836 .834 .845 .862 .886 .910 .915 .921 .965	.857 .859 .862 .874 .916 .934 .934 .954 .954	.866 .862 .867 .875 .879 .896 .918 .935 .918 .954	.874 .872 .883 .884 .900 .963 .910 .957 .910	.882 .883 .890 .891 .903 .940 .940 .942 .942 .967 .972	.8.6.6.6.6.6.6.6.6.6.6.6.6.6.6.6.6.6.6.
4.09 4.88 4.58 4.53 4.53 4.53 4.53 4.53 4.53 4.53 4.53	867 858 859 99 95 66 68 959 959 959 959 959 959 959 959 959 95	\$\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\	.888 .893 .904 .903 .948 .979 .979 .963 .969	.897 .893 .896 .905 .909 .944 .955 .959 .969 .983 .989	.94.95.95.95.95.95.95.95.95.95.95.95.95.95.	917 927 927 927 927 927 927 927 927 927 92	£5555555555555555555555555555555555555	873 876 889 889 933 946 957 958 958	86.69.99.99.99.99.99.99.99.99.99.99.99.99	.883 .883 .886 .895 .933 .948 .954 .954 .957 .958 .999	\$6 \$6 \$6 \$6 \$6 \$6 \$6 \$6 \$6 \$6 \$6 \$6 \$6 \$.907 .904 .910 .910 .918 .946 .938 .946 .936 .976 .976 .976 .988	.836 .834 .857 .862 .886 .910 .915 .951 .951 .975	.877 .856 .870 .874 .934 .934 .934 .954 .954 .954	.866 .866 .867 .875 .875 .876 .978 .974 .975 .975 .975	.875 .883 .884 .900 .937 .937 .937 .937 .937 .937 .937 .937	.882 .883 .890 .891 .903 .924 .940 .942 .967 .972 .973	.8.6.6.6.6.6.6.6.6.6.6.6.6.6.6.6.6.6.6.
4.4.5.5.6.3.3.4.4.3.3.4.4.3.3.4.4.3.3.4.4.3.3.4.4.3.3.4.4.3.3.4.4.3.3.3.4.3	867 868 889 889 889 889 889 889 889 889 889	\$\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\	.888 .893 .904 .903 .948 .979 .960 .961 .963 .969 .969	.897 .893 .896 .905 .903 .934 .955 .959 .979 .978 .989	\$4.555.555.555.555.555.555.555.555.555.5	.917 .927 .927 .927 .925 .925 .925 .925 .925 .925 .925 .925	££££888833855£885	.873 .870 .889 .888 .983 .944 .954 .954 .954 .958 .989	86.63.34.65.63.86.65.86.65.86.65.86.65.86.65.86.65.86.65.86.65.86.65.86.65.86.65.86.65.86.65.86.65.86.65.86.65	883 883 886 895 933 948 956 957 958 959 957	\$6.856.504.505.505.505.505.505.505.505.505.505	.907 .904 .910 .910 .946 .938 .946 .936 .976 .976 .988 .989	.836 .834 .844 .856 .886 .931 .915 .915 .951 .971 .966 .971	857 858 850 854 855 858 858 858 858 858 858 858 858	86 86 55 85 85 85 85 85 85 85 85 85 85 85 85	. Bri	.883 .890 .891 .903 .924 .940 .940 .942 .947 .944 .966	. 8 . 8 . 9 . 9 . 9 . 9 . 9 . 9 . 9 . 9 . 9 . 9
4.4.5.56.33.44.4.33.43.44.4.34.4.4.34.	8678888888888989556558888888888888888888	######################################	.888 .886 .893 .903 .923 .929 .979 .979 .989 .989 .999	.897 .893 .896 .909 .909 .924 .975 .979 .978 .989 .989 .989	.94 .90 .91 .91 .93 .95 .95 .95 .95 .95 .95 .95 .95 .95 .95	917 907 907 907 907 907 907 907 907 907 90	££\$£\$\$\$\$\$\$\$\$\$\$\$	873 870 889 889 993 954 954 955 959 959	80 63 54 54 54 54 55 55 56 55 56 55 56 55 56 55 56 55 56 55 56 56	85388 855 857 3338 844 65 858 856 856 856 856 856 856 856 856	\$6.856.504.505.505.505.505.505.505.505.505.505	.907 .904 .910 .910 .918 .918 .916 .916 .916 .916 .916 .916 .916 .916	.836 .834 .844 .857 .886 .930 .915 .951 .966 .971 .966 .971	857 858 850 855 850 855 855 855 855 855 855	86 86 55 85 85 85 85 85 85 85 85 85 85 85 85	######################################	.862 .883 .890 .893 .940 .942 .942 .942 .967 .976 .984 .985 .986	
**************************************	\$55588 \$855 \$555 \$555 \$555 \$555 \$555 \$5	\$\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\	.888 .886 .893 .903 .921 .948 .977 .963 .963 .969 .999 .999	.897 .893 .896 .909 .924 .955 .959 .959 .959 .959 .959 .959	.94 .94 .94 .95 .95 .95 .95 .95 .95 .95 .95 .95 .95	91 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	888888885885588888	\$170 \$200 \$200 \$330 \$350 \$350 \$450 \$550 \$550 \$550 \$550 \$550 \$550 \$5	\$6.69.545 B. 5.55 B. 5	85388 855 857 8338 846 65 858 856 856 856 856 856 856 856 856	\$6.856.556.555.556.556.556.556.556.556.55	.907 .904 .910 .910 .916 .916 .916 .916 .916 .916 .916 .916	.836 .834 .834 .836 .836 .933 .935 .935 .971 .975 .987 .987	8775 886 874 874 875 875 875 875 875 875 875 875 875 875	***************************************	.875 .884 .900 .937 .937 .937 .937 .937 .939 .939 .939	.862 .883 .890 .890 .903 .940 .942 .967 .964 .964 .965 .964	.86 .86 .86 .85 .85 .85 .85 .85 .85 .85 .85 .85 .85
4.4.8.9.8.4.4.3.4.4.3.4.4.3.4.4.3.4.4.3.4.4.3.4.4.3.4.4.3.4.4.3.4.4.3.4.4.3.4.4.3.4.4.3.4.4.3.4.4.4.3.4	\$5.56 \$5.56 \$5.50	#628858535555555855558555585555	888 886 893 903 903 903 903 903 903 903 903 903 9		.94 .95 .95 .95 .95 .95 .95 .95 .95 .95 .95	94 95 95 95 95 95 95 95 95 95 95 95 95 95	£55£5555555555555555555555555555555555	\$1000000000000000000000000000000000000	86 6 3 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	883 883 885 885 885 885 885 885 885 885	\$60 \$64 \$94 \$95 \$95 \$95 \$95 \$95 \$95 \$95 \$95 \$95 \$95	.909 .904 .916 .934 .935 .935 .935 .935 .935 .935 .935 .935	856 834 834 836 836 933 935 936 937 937 938 937	. 857 . 859 . 870 . 874 . 894 . 914 . 914 . 914 . 914 . 915 . 915 . 916 . 916 . 916 . 916 . 916 . 916 . 916 . 916 . 916	*****************	.874 .883 .884 .900 .937 .937 .937 .937 .937 .937 .937 .937	.862 .863 .890 .903 .940 .940 .940 .947 .956 .964 .969	
4.0934 4.5384 4.	\$55588 \$855 \$555 \$555 \$555 \$555 \$555 \$5	\$\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\	.888 .886 .893 .903 .921 .948 .977 .963 .963 .969 .999 .999	.897 .893 .896 .909 .924 .955 .959 .959 .959 .959 .959 .959	.94 .94 .94 .95 .95 .95 .95 .95 .95 .95 .95 .95 .95	91 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	888888885885588888	\$170 \$200 \$200 \$330 \$350 \$350 \$450 \$550 \$550 \$550 \$550 \$550 \$550 \$5	\$6.69.545 B. 5.55 B. 5	85388 855 857 8338 846 65 858 856 856 856 856 856 856 856 856	\$6.856.556.555.556.556.556.556.556.556.55	.907 .904 .910 .910 .916 .916 .916 .916 .916 .916 .916 .916	.836 .834 .834 .836 .836 .933 .935 .935 .971 .975 .987 .987	8775 886 874 874 875 875 875 875 875 875 875 875 875 875	***************************************	.875 .884 .900 .937 .937 .937 .937 .937 .939 .939 .939	.862 .883 .890 .890 .903 .940 .942 .967 .964 .964 .965 .964	.86 .86 .86 .85 .85 .85 .85 .85 .85 .85 .85 .85 .85

TABLE I.- LOCAL VELOCITY RATIO, U/V - Concluded

(c) The 1-series spinner, no cowl

Radial station, in.	M=0.15	M=0.20	M=0 • 40	M=0.50	M=0.60	M =0.70	M=0.80
3.44	1.071	1.079	1.088	1.092	1.102	1.108	1.124
3.69	1.070	1.078	1.082	1.095	1.102	1.109	1.124
3.94	1.063	1.068	1.077	1.079	1.089	1.094	1.107
4.19	1.049	1.063	1.062	1.067	1.076	1.081	1.092
4.44	1.042	1.057	1.059	1.063	1.071	1.076	1.088
4.94	1.021	1.037	1.043	1.046	1.059	1.064	1.071
5.44	1.020	1.030	1.035	1.038	1.050	1.052	1.065
5.94	1.019	1.029	1.028	1.036	1.044	1.046	1.055
6.44	1.013	1.019	1.020	1.024	1.031	1.034	1.043
7.44	1.005	1.018	1.014	1.014	1.023	1.027	1.032
8.44	•997	1.012	1.015	1.014	1.023	1.027	1.033
9.44	1.003	1.011	1.008	1.014	1.021	1.025	1.035
10.44	1.002	1.005	1.005	1.006	1.011	1.013	1.013
12.44	1.001	1.004	1.001	1.004	1.004	1.005	
14.44	•999	•997	1.005	1.003	1.006	1.007	1.004
16.44	•998	•996	-999	•997	1.002	1.003	1.001
18.44	•997	•995	•996	•996	1.002	1.002.	
20.44	•997	1.000	1.000	1.004	1.004	1.005	1.001
22.44	•899	•999	-997	1.001	1.001	1.002	1.000
24.44	1.003	1.009	1.001	1.004	1.002	1.003	•998
26.44	•995	1.003	1.000	1.002	1.005	1.003	997
28.44	1.002	1.008	1.001	1.001	1.004	1.005	•999
30.44	1.002	1.008	1.003	1.001	1.003	1.003	1.001
32.44	1.001	1.007	1.004	1.006	1.008	1.004	1.001

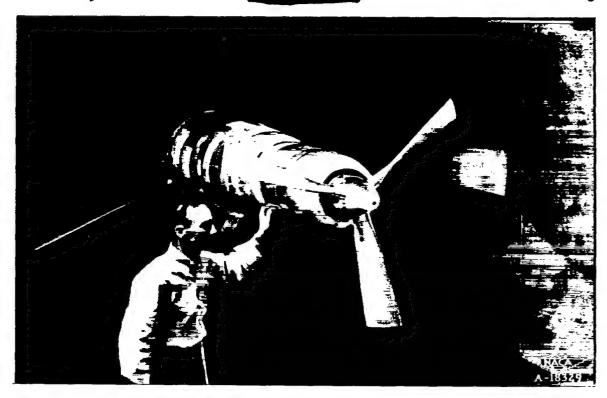


Figure 1.- The model mounted on the 1000-horsepower propeller dynamometer in the 12-foot pressure wind tunnel.

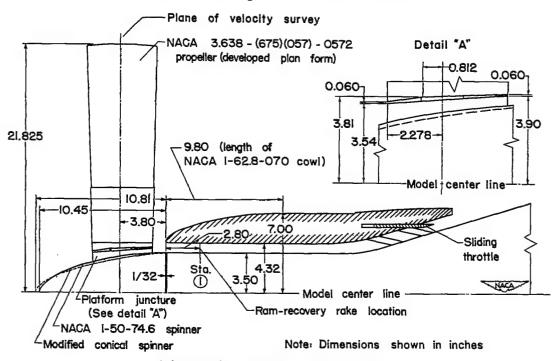


Figure 2.- Model arrangement.



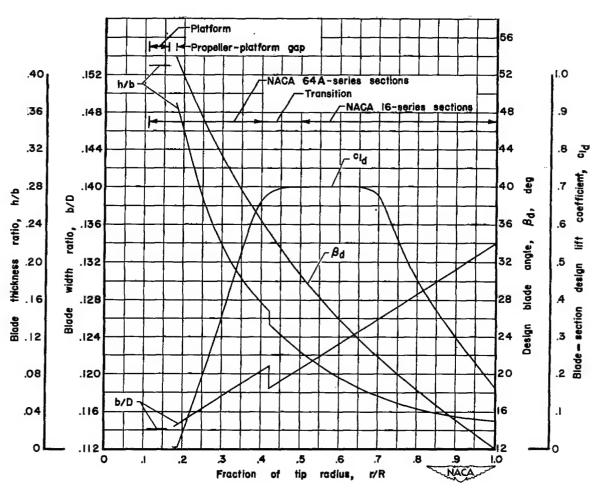


Figure 3.- Plan-form and blade-form curves for the model propeller having the designation NACA 3.638-(675)(057)-0572.

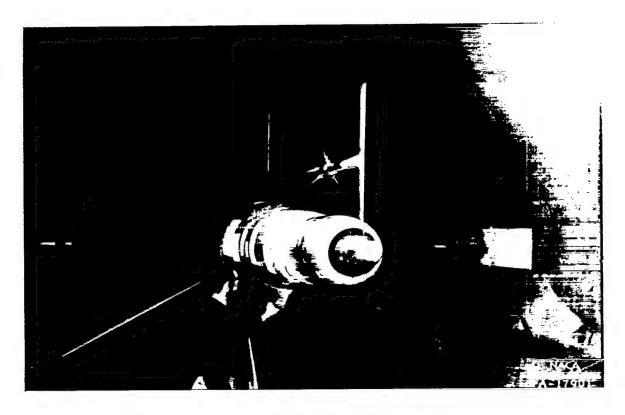


Figure 4.- Photograph of the survey rake.

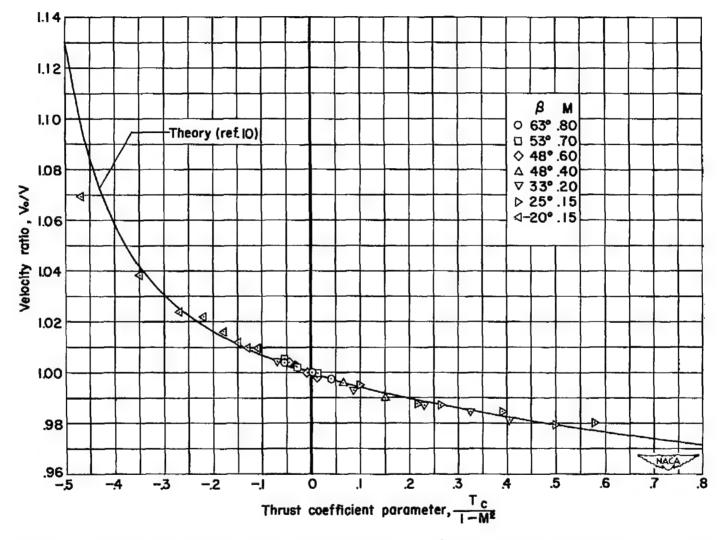
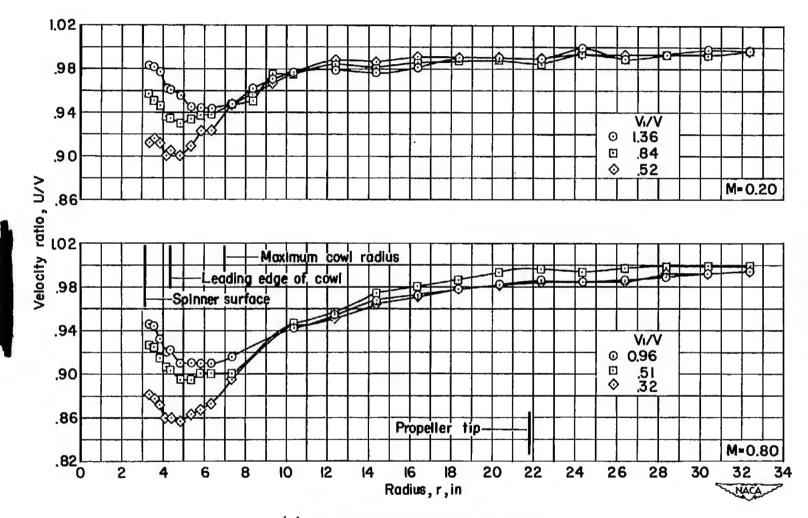
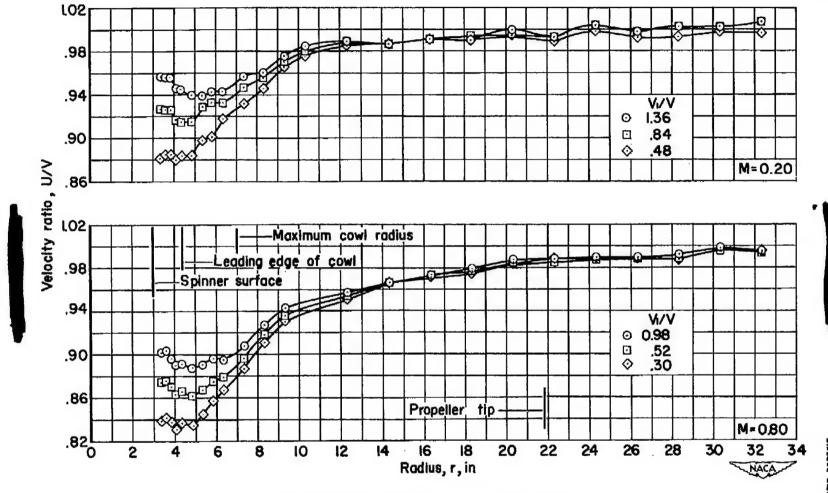


Figure 5.- Tunnel-wall-interference correction for a 3.6-foot-diameter propeller in the Ames 12-foot pressure wind tunnel.



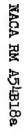
(a) The 1-series spinner with cowl.

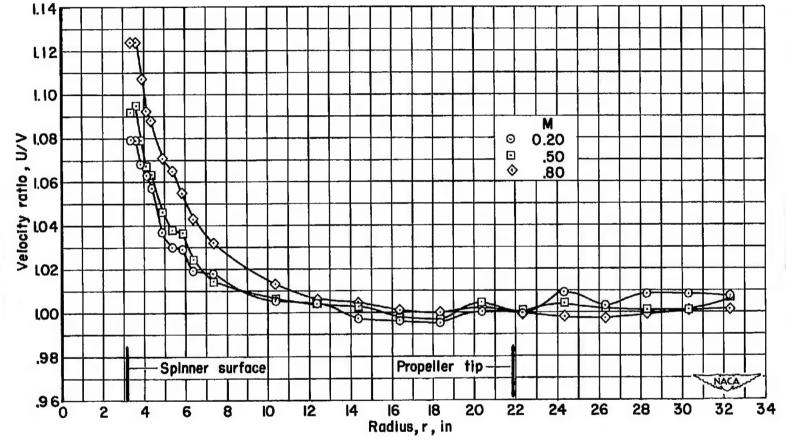
Figure 6.- Typical radial distributions of the local velocity ratio in the plane of the propeller.



(b) Modified conical spinner with cowl.

Figure 6.- Continued.





(c) The 1-series spinner, no cowl.

Figure 6.- Concluded.

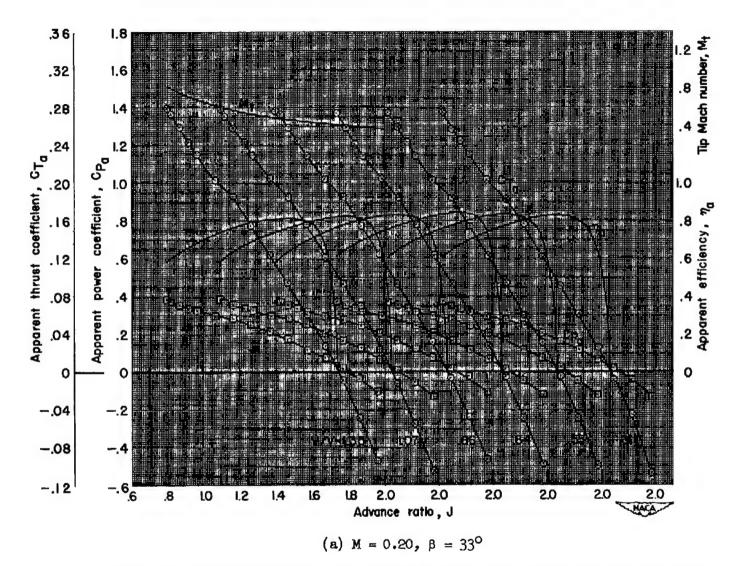
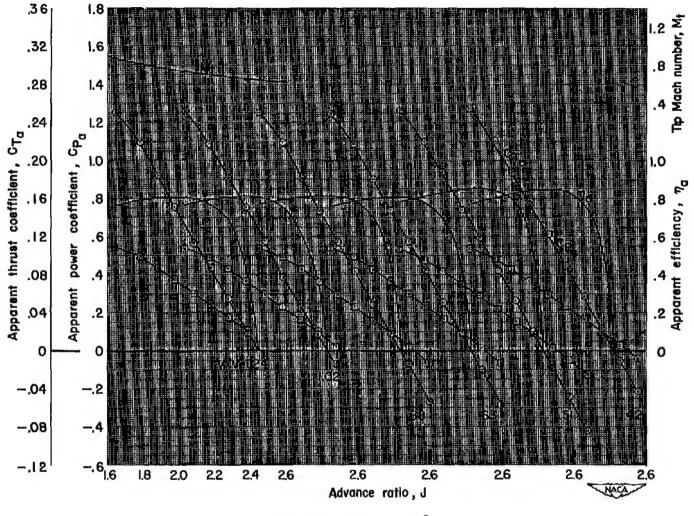
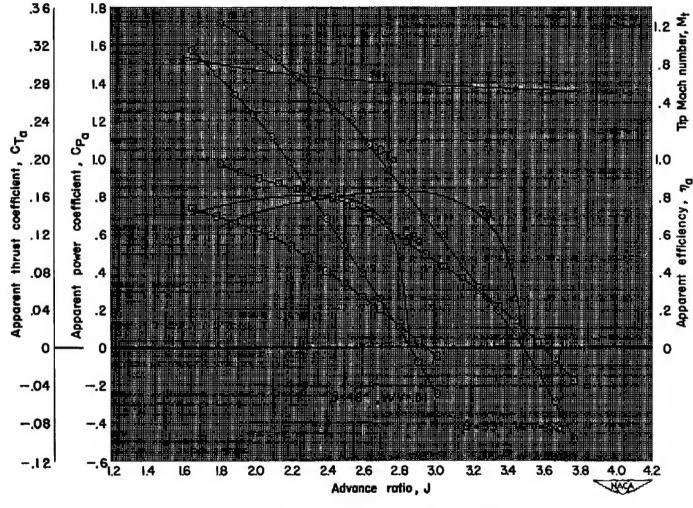


Figure 7.- Characteristics of the propeller with the 1-series spinner and cowl.



(b) M = 0.40, $\beta = 43^{\circ}$

Figure 7.- Continued.



(c) M = 0.40, $\beta = 48^{\circ}$ and 53°

Figure 7.- Continued.

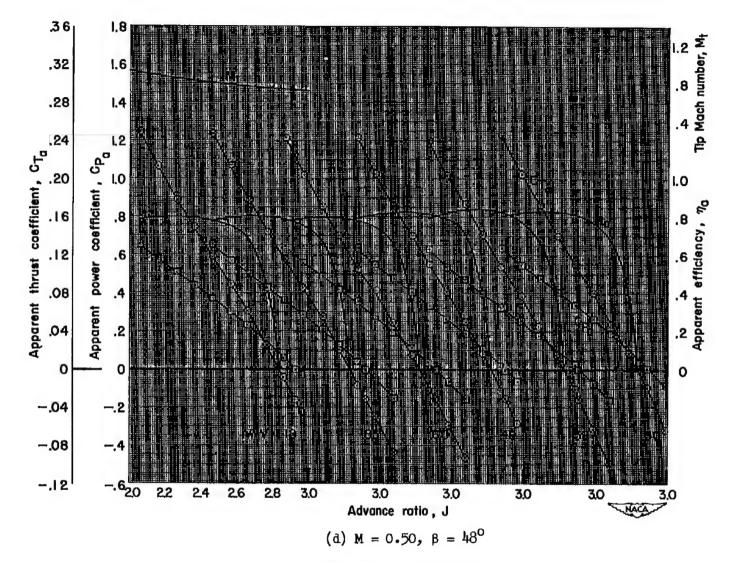


Figure 7.- Continued.

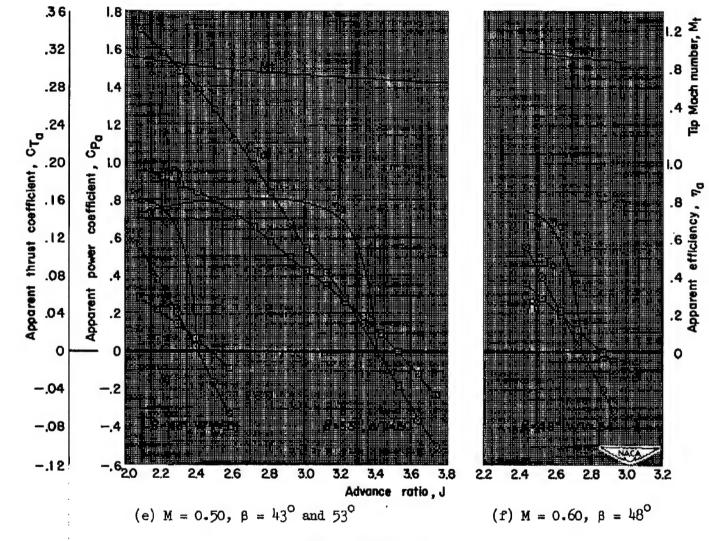
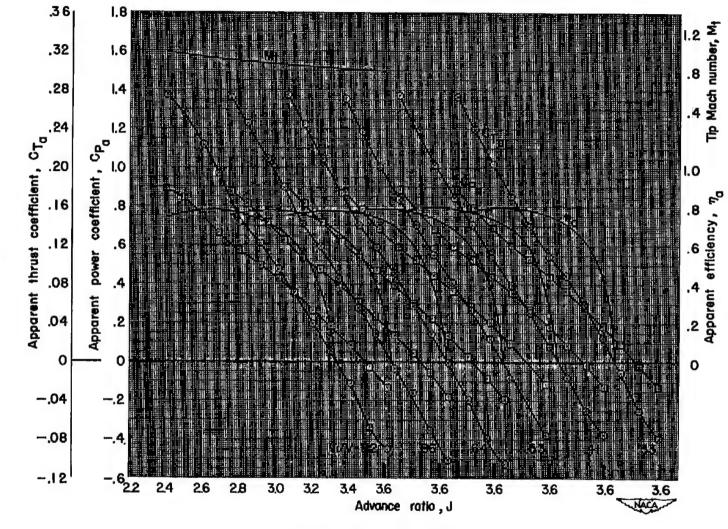
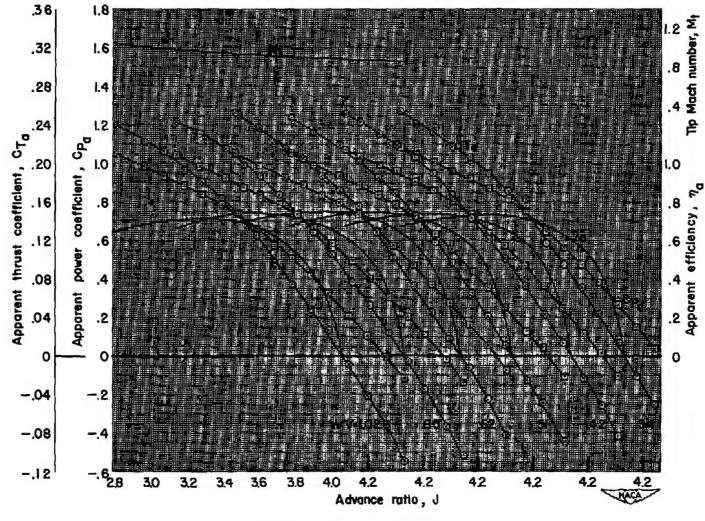


Figure 7.- Continued.



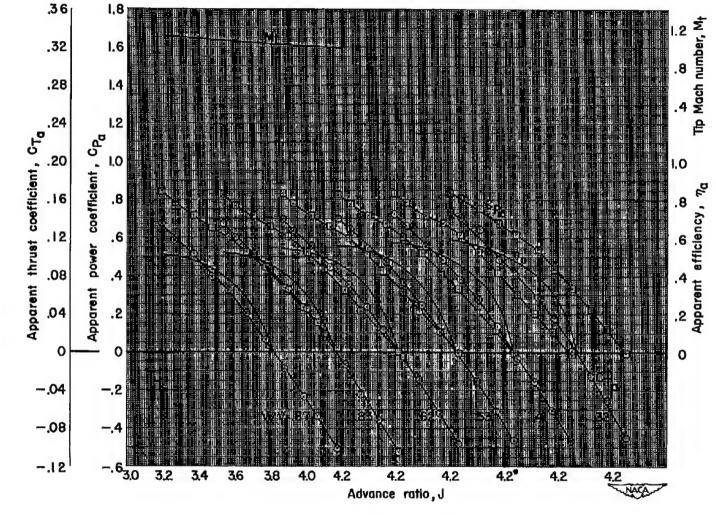
(g) M = 0.60, $\beta = 53^{\circ}$

Figure 7.- Continued.



(h) M = 0.70, $\beta = 58.5^{\circ}$

Figure 7.- Continued.



(i) M = 0.80, $\beta = 58.5^{\circ}$

Figure 7.- Concluded.

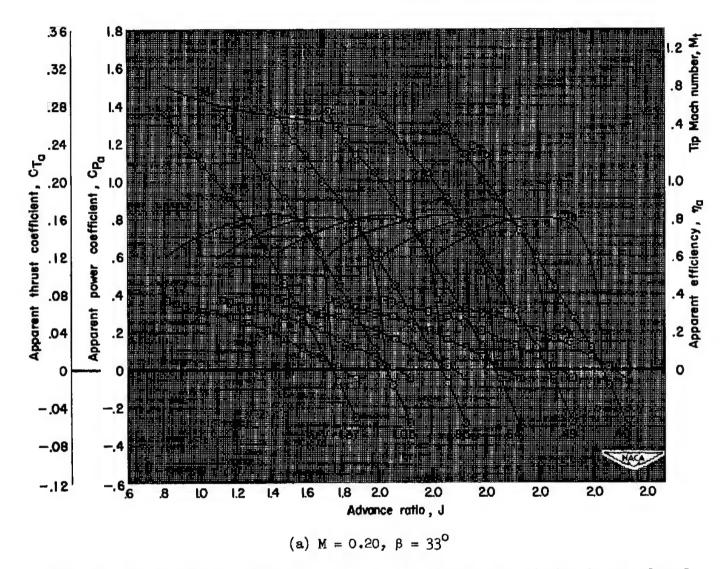


Figure 8.- Characteristics of the propeller with the modified conical spinner and cowl.

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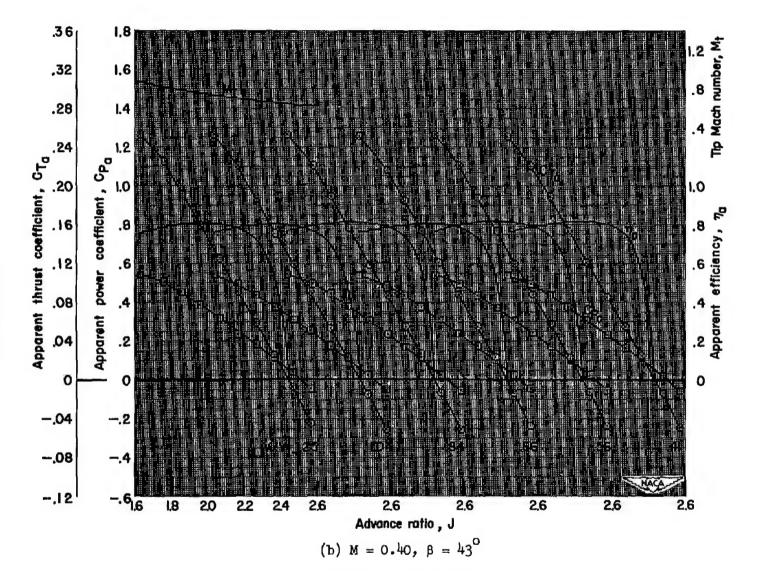
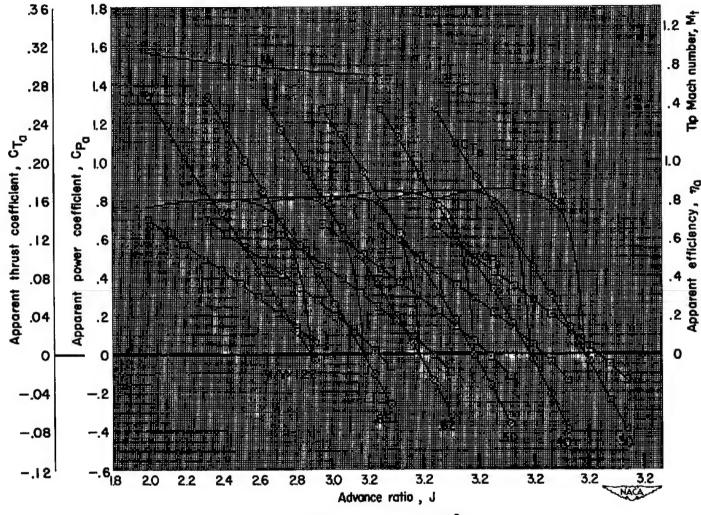
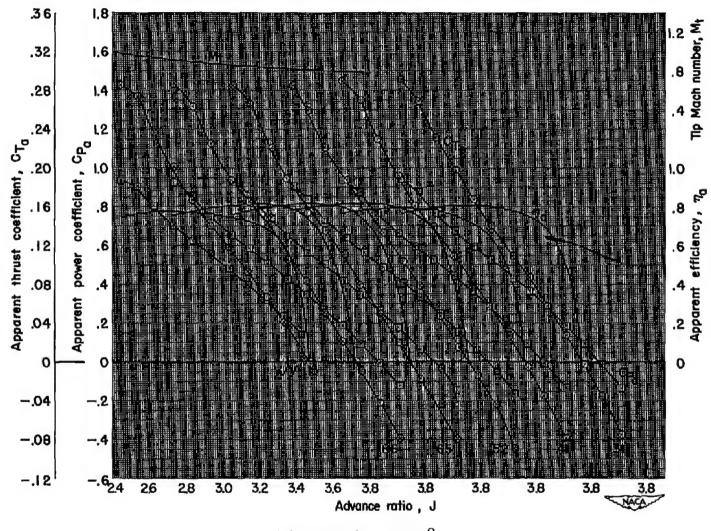


Figure 8.- Continued.



(c) M = 0.50, $\beta = 48^{\circ}$

Figure 8.- Continued.



(d) M = 0.60, $\beta = 53^{\circ}$

Figure 8.- Continued.

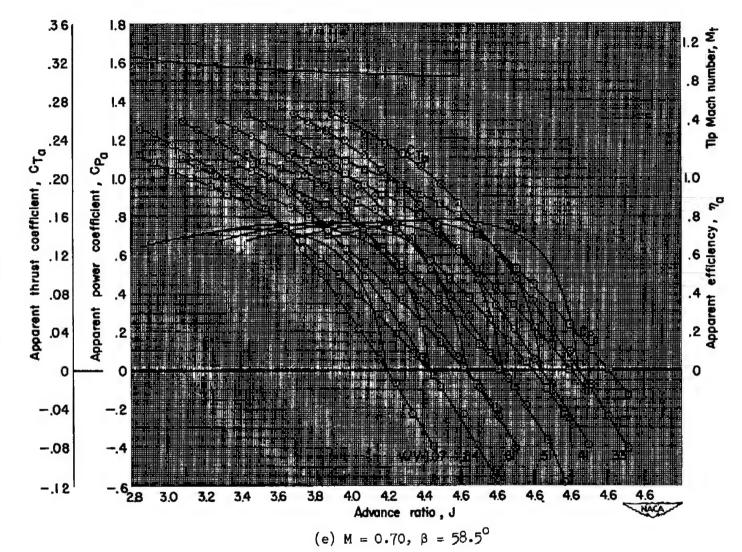
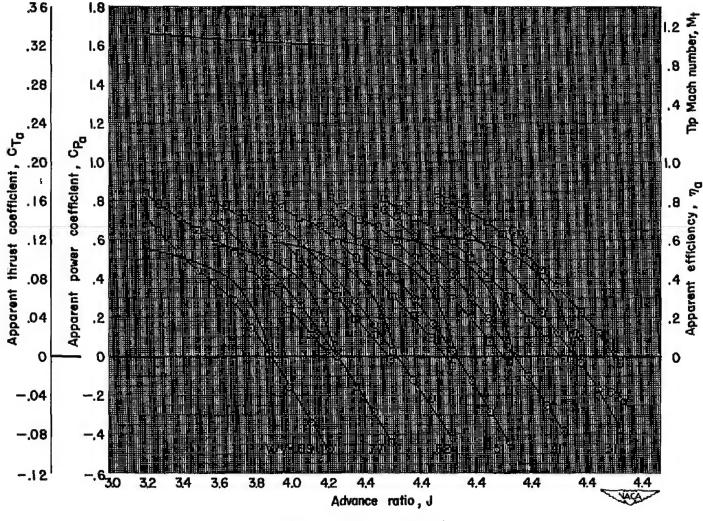


Figure 8.- Continued.



(f) M = 0.80, $\beta = 58.5^{\circ}$

Figure 8.- Concluded.

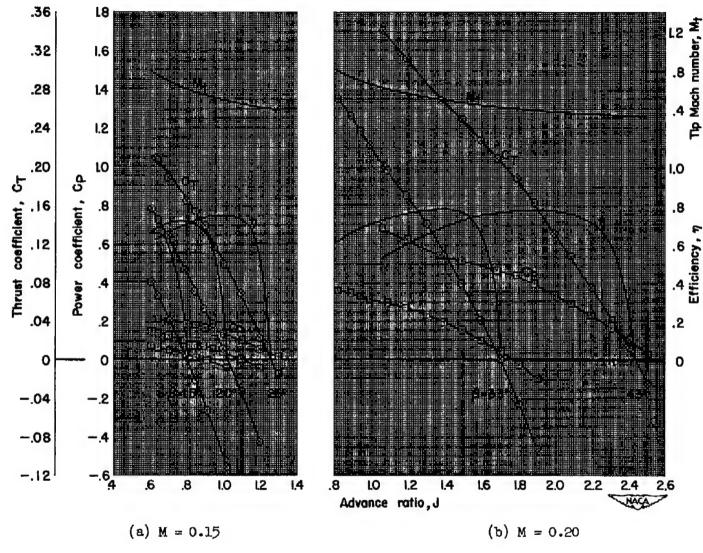
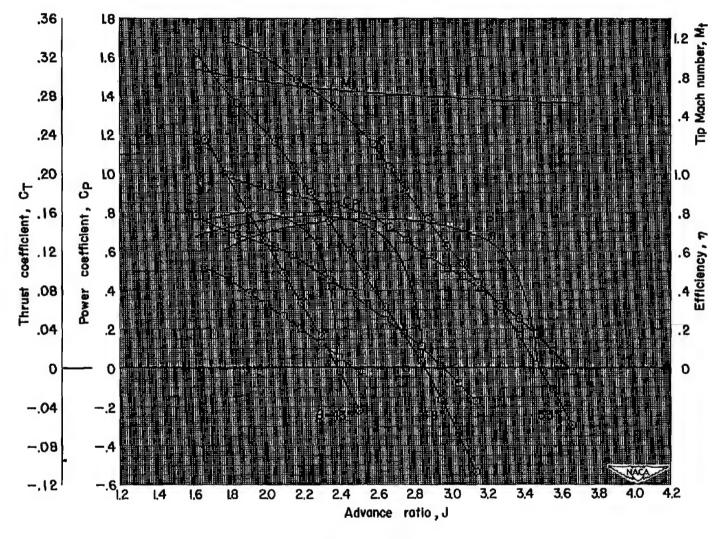
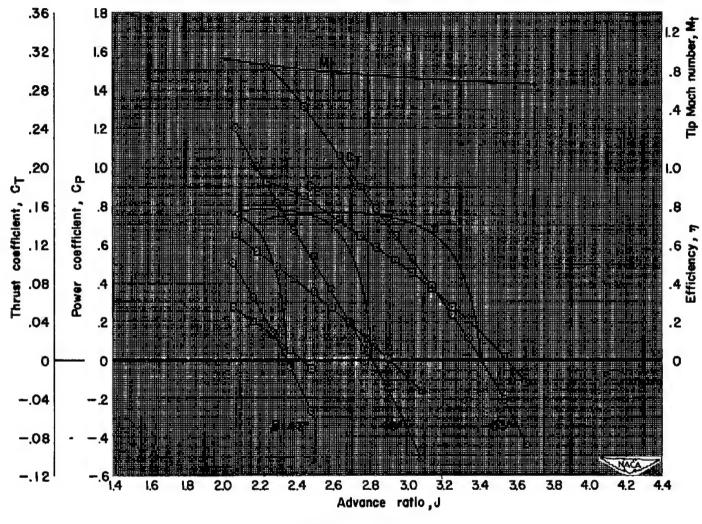


Figure 9.- Characteristics of the isolated propeller-spinner combination.



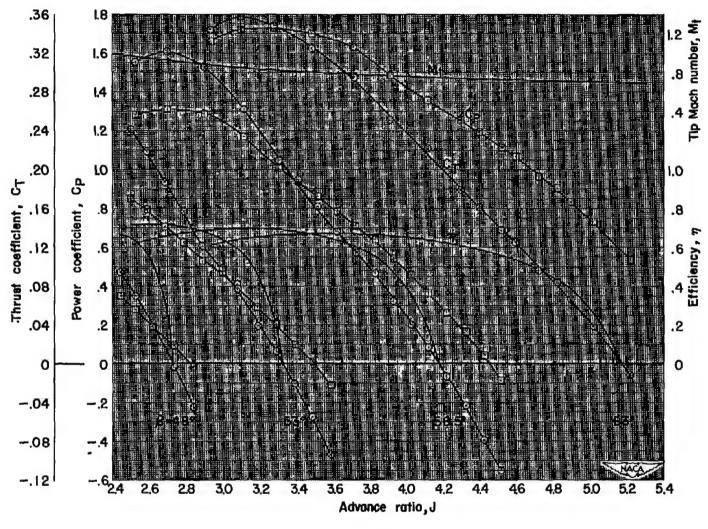
(c) M = 0.40

Figure 9.- Continued.



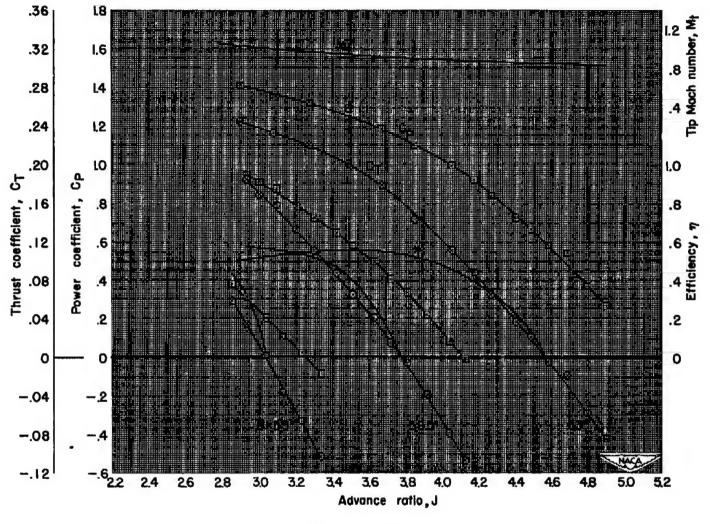
(d) M = 0.50

Figure 9.- Continued.



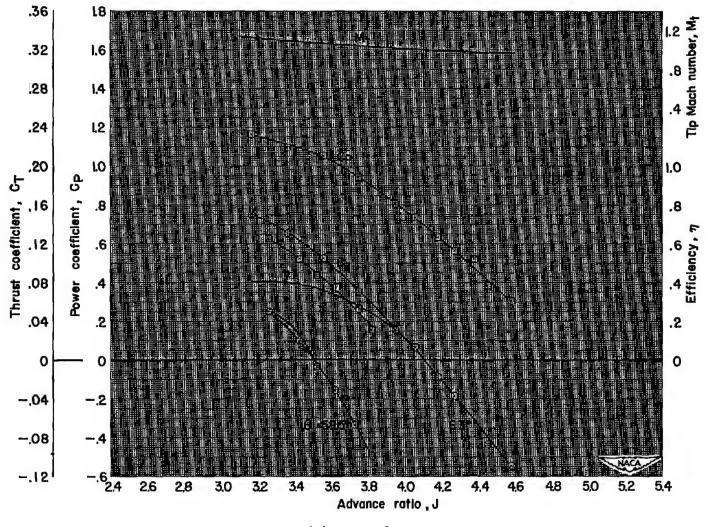
(e) M = 0.60

Figure 9.- Continued.



(f) M = 0.70

Figure 9.- Continued.



(g) M = 0.80

Figure 9 .- Concluded.

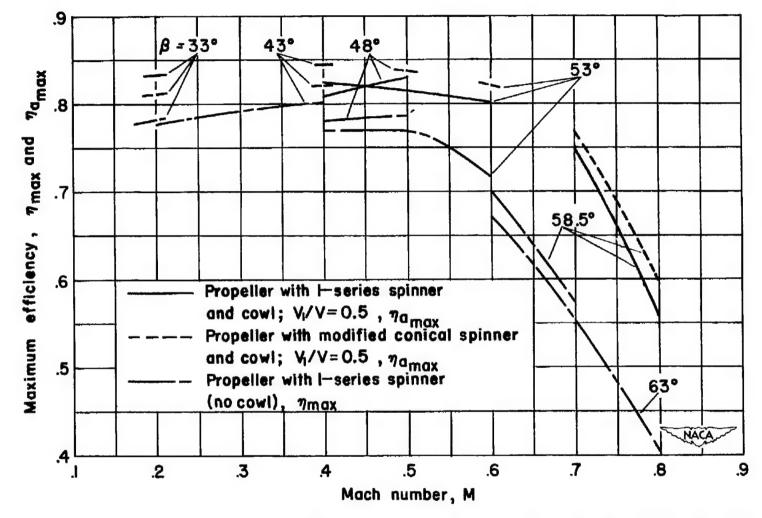


Figure 10.- Comparison of the maximum efficiency of the propeller with and without the cowl.

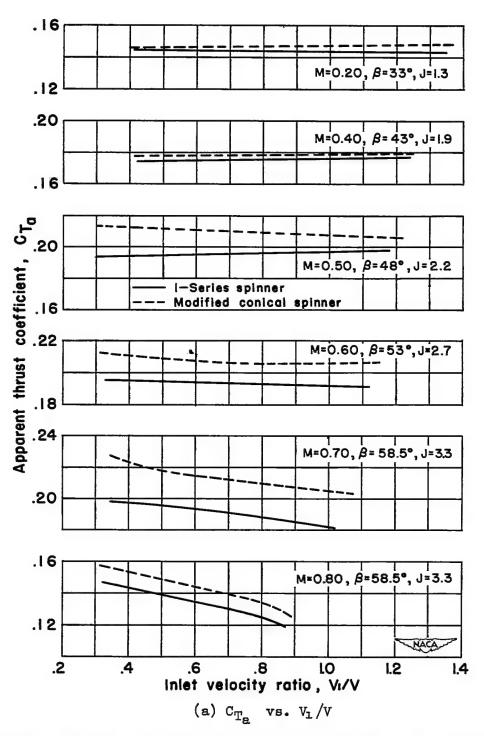


Figure 11.- Typical effect of inlet velocity ratio on the apparent thrust and power coefficients of the propeller.



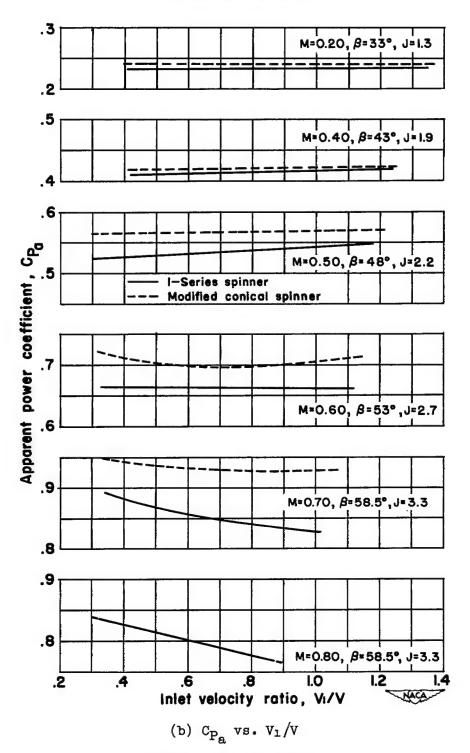


Figure 11.- Concluded.



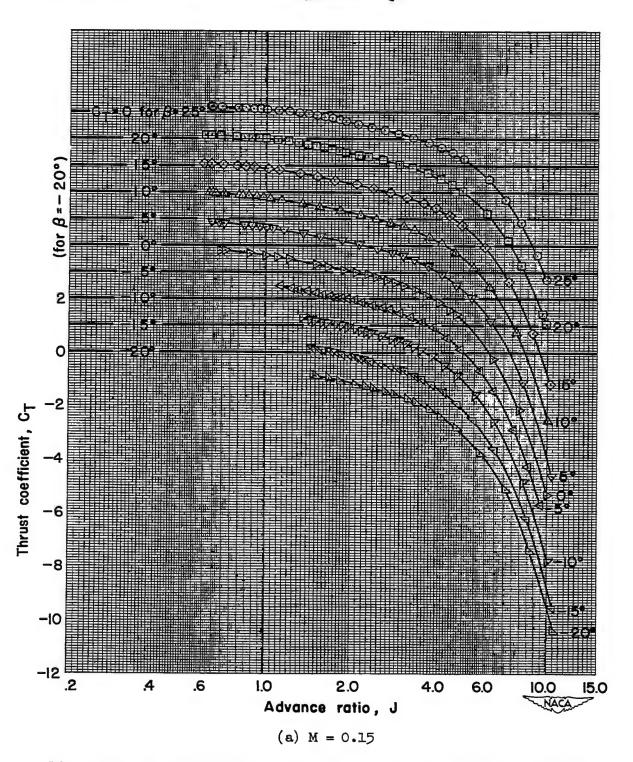
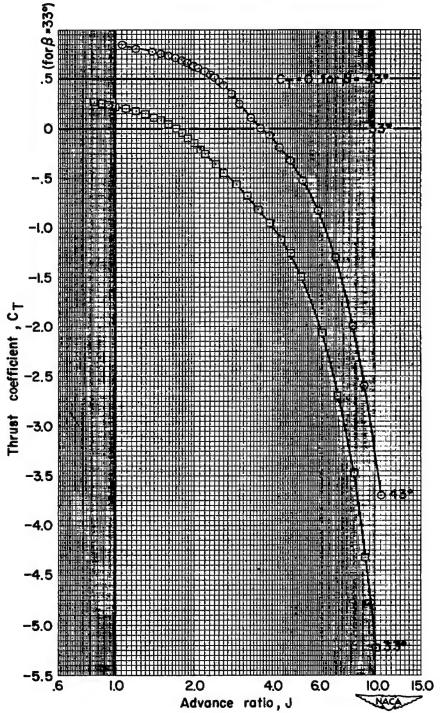


Figure 12.- Negative thrust coefficients for the isolated propellerspinner combination.





(b) M = 0.20

Figure 12.- Continued.





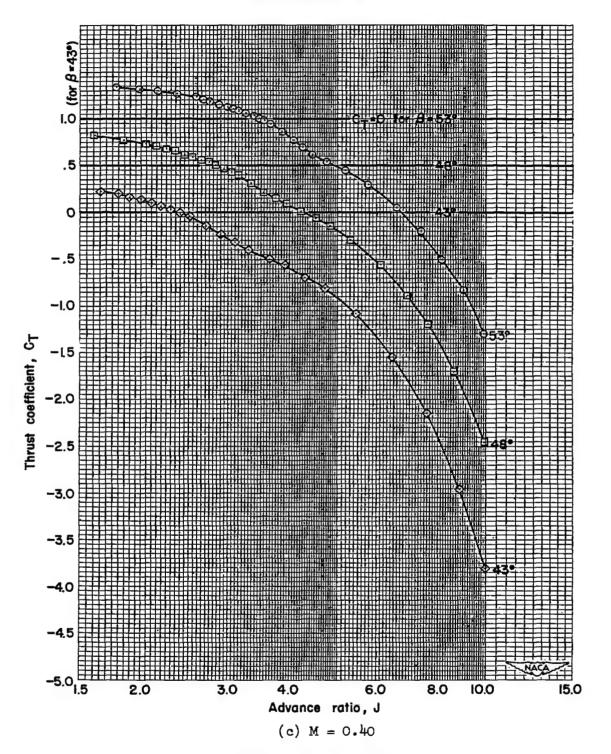


Figure 12.- Continued.



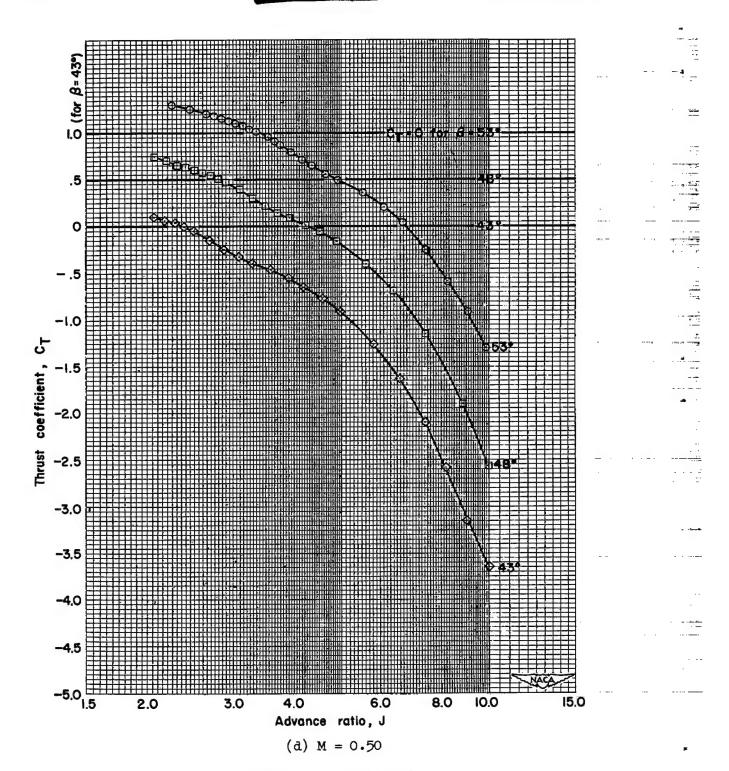
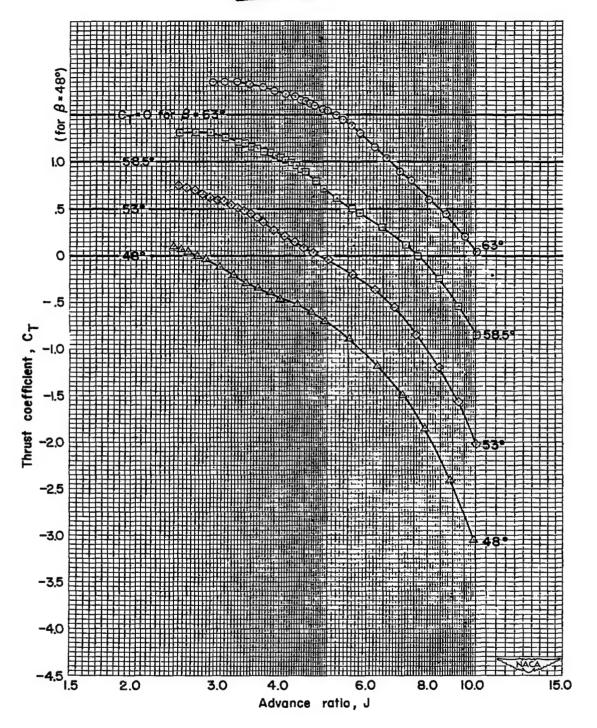


Figure 12.- Continued.



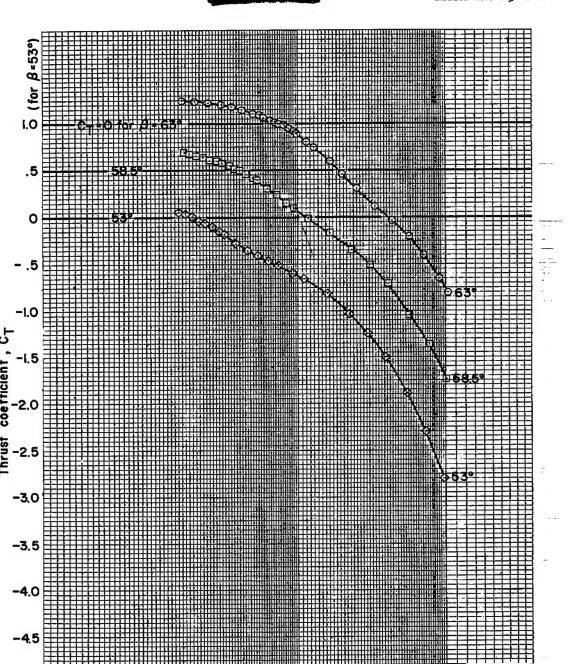




(e) M = 0.60

Figure 12.- Continued.





(f) M = 0.70

Advance ratio, J

4.0

3.0

2.0

8.0

6.0

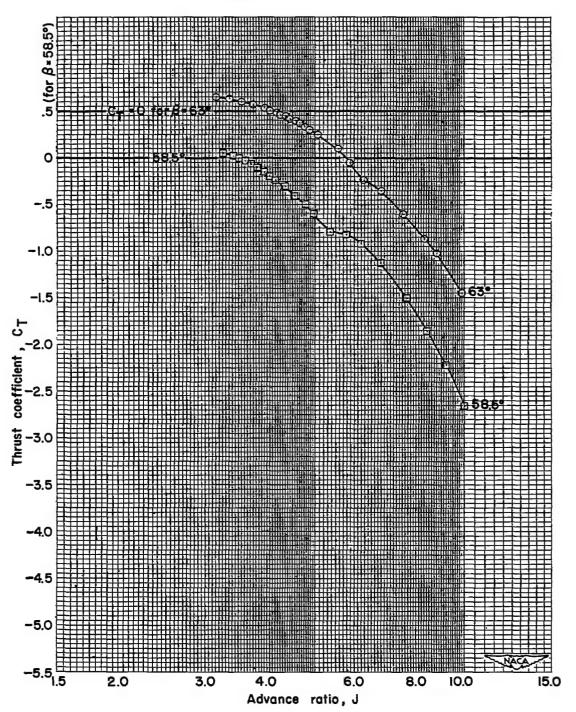
10.0

15.0

Figure 12.- Continued.



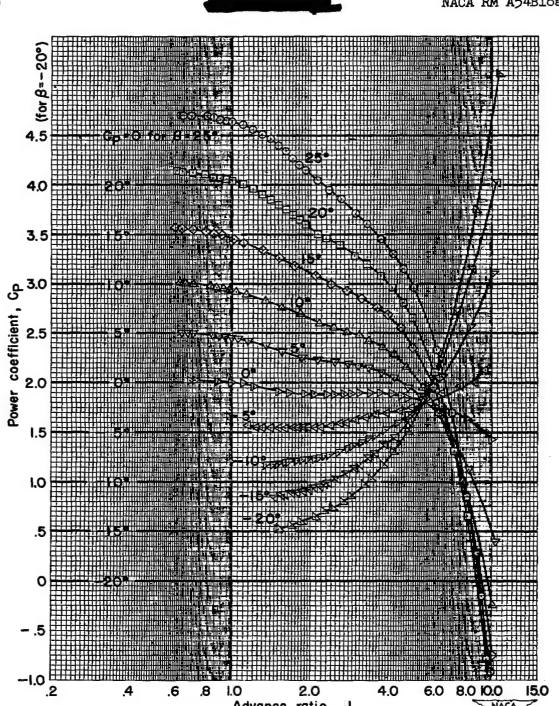




(g) M = 0.80

Figure 12.- Concluded.





(a) M = 0.15

Advance ratio, J

2.0

4.0

6.0 8.0 10.0

.6

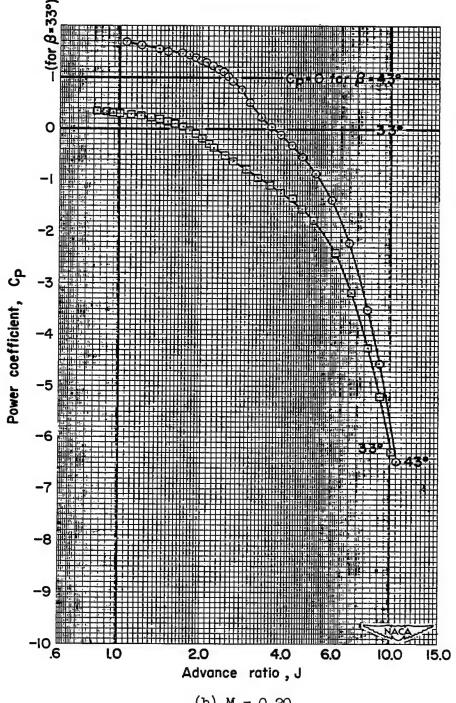
8.

1.0

Figure 13.- Power coefficients for the isolated propeller-spinner combination in negative thrust.



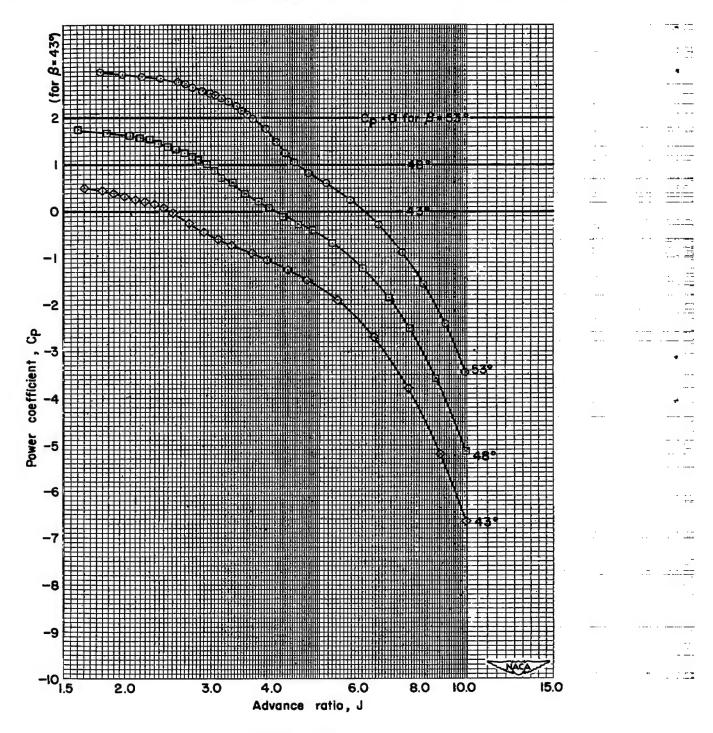




(b) M = 0.20

Figure 13.- Continued.





(c) M = 0.40

Figure 13.- Continued.





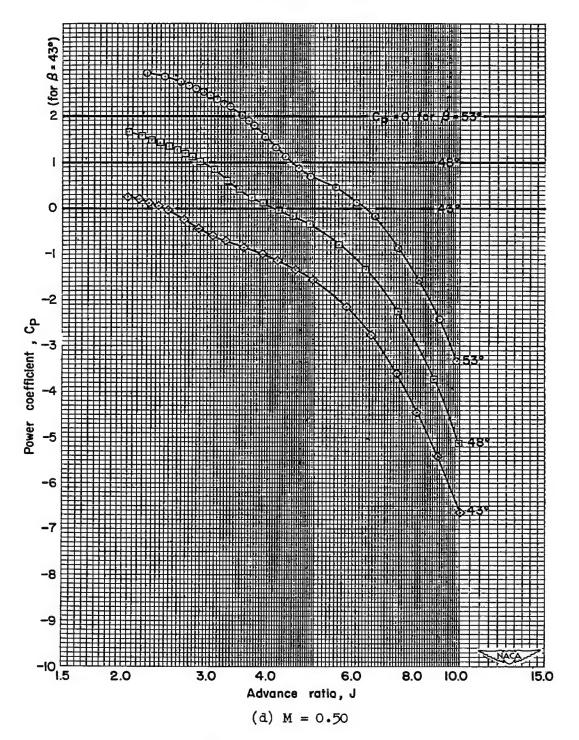
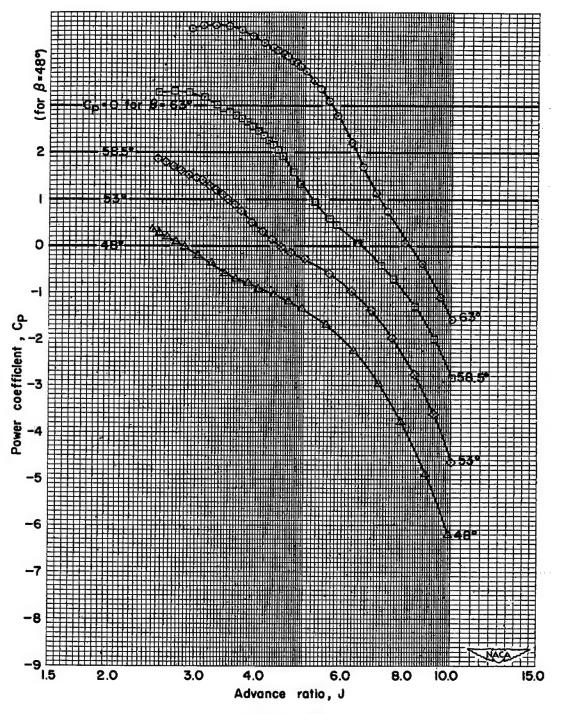


Figure 13.- Continued.





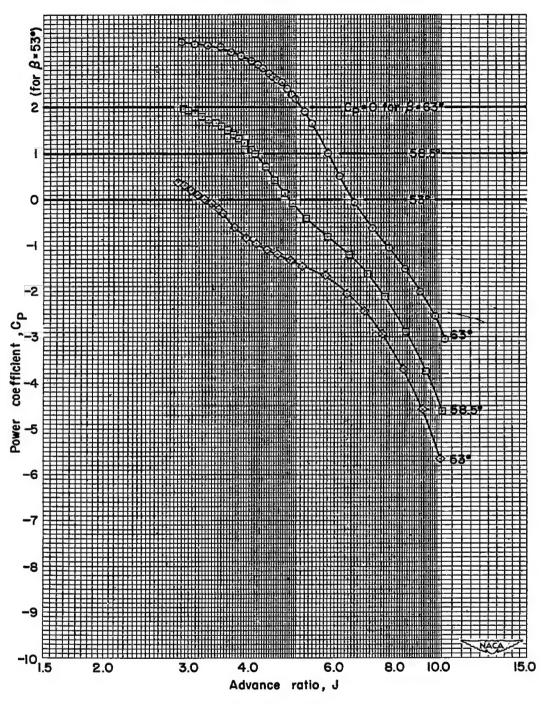


(e) M = 0.60

Figure 13.- Continued.







(f) M = 0.70

Figure 13.- Continued.



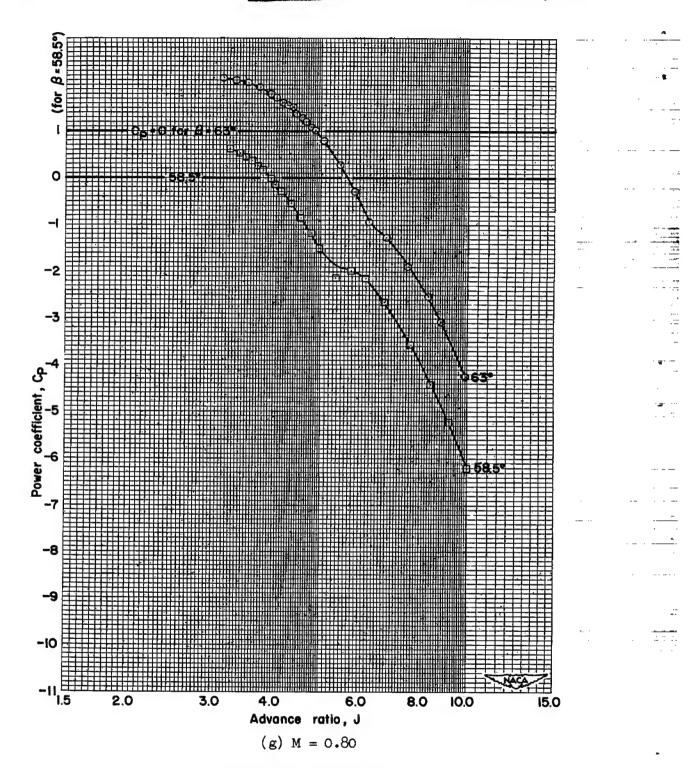


Figure 13.- Concluded.



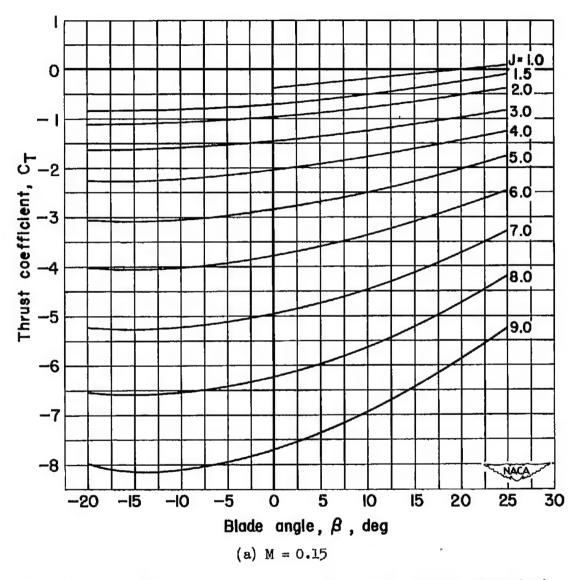


Figure 14.- The effect of blade angle on the negative-thrust characteristics of the propeller.

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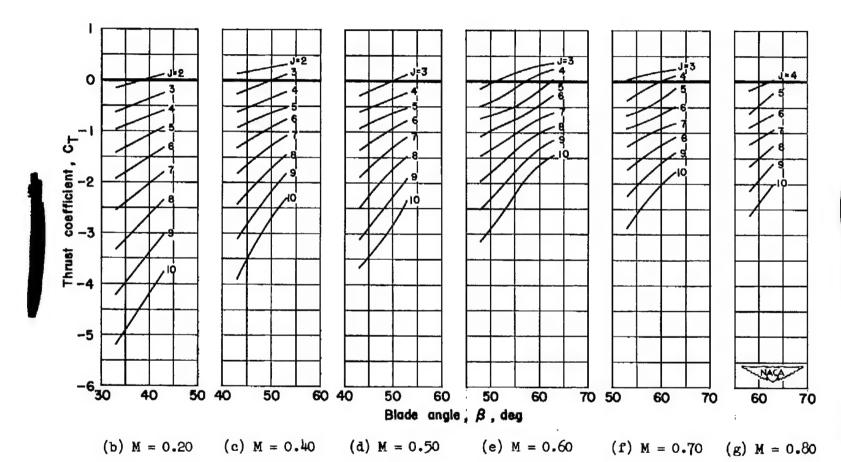


Figure 14.- Concluded.

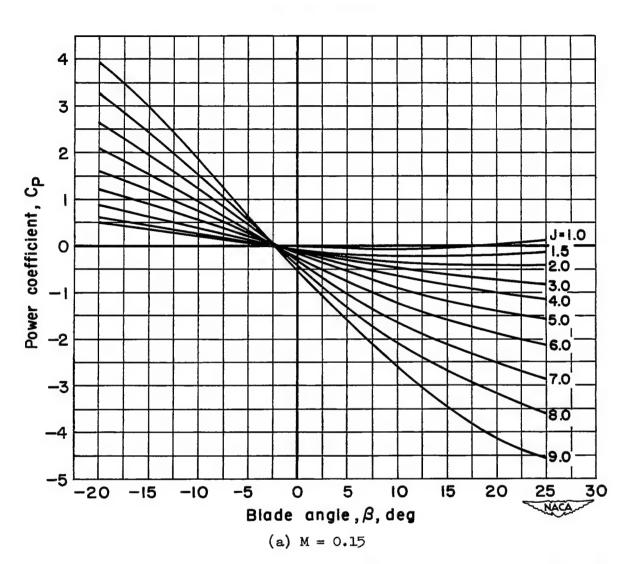


Figure 15.- The effect of blade angle on the power coefficients for the propeller in negative thrust.

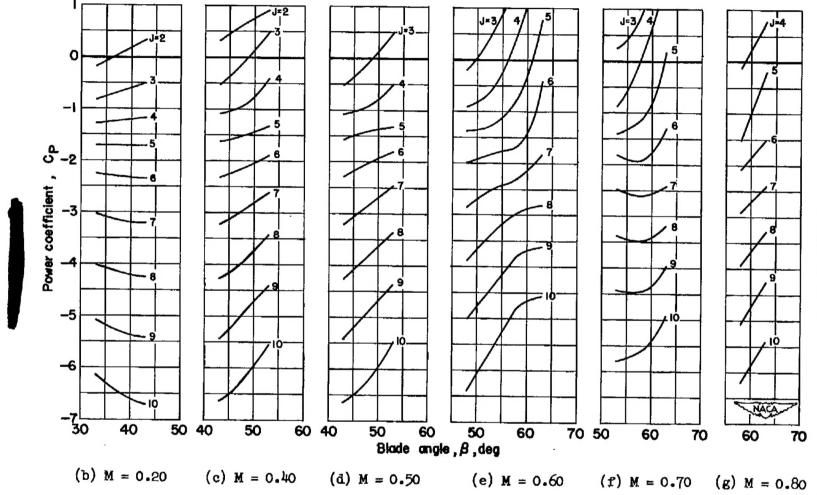
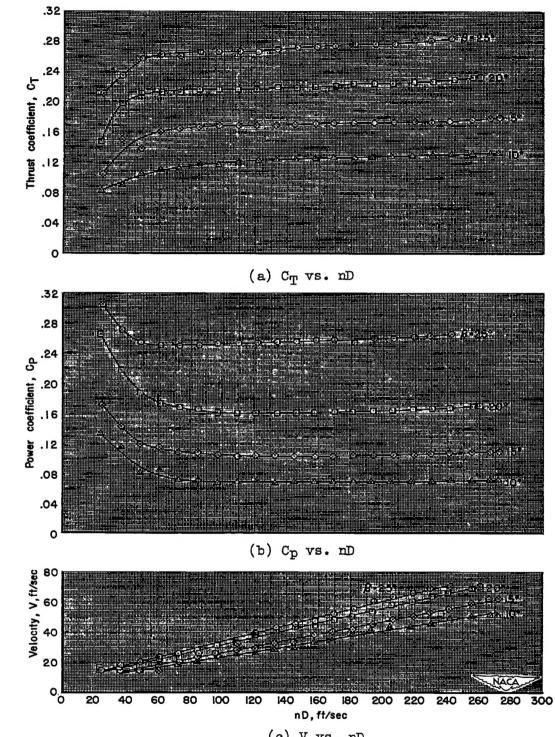


Figure 15.- Concluded.

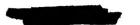




(c) V vs. nD

Figure 16.- Characteristics of the isolated propeller-spinner combination at near static conditions.





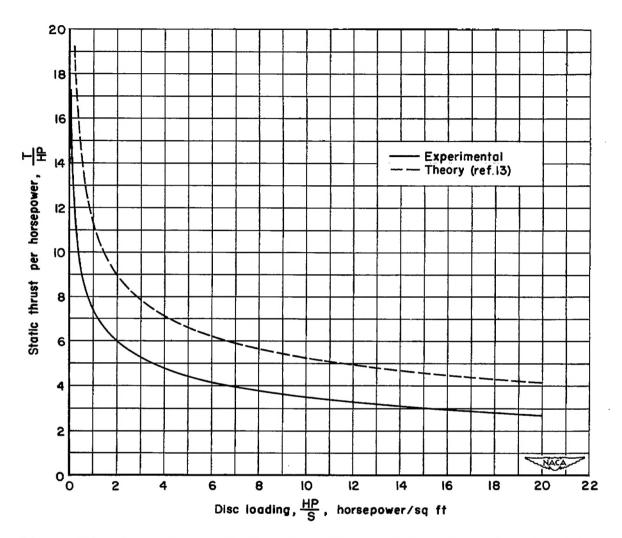


Figure 17.- Comparison with theory of the variation of sea-level static thrust per horsepower with power disc loading for the isolated propeller-spinner combination.



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